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# Modular Multipurpose Space Station Study

## Section 4—PRELIMINARY SPECIFICATIONS

### FINAL REPORT

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Houston, Texas  
30 July 1965



LOCKHEED-CALIFORNIA COMPANY • BURBANK  
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION



## VOLUME INDEX

## MODULAR MULTIPURPOSE SPACE STATION STUDY

The complete study, consisting of six sections, an appendix, and a condensed summary, is contained in the following seven volumes.

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- { 3. MODULAR SPACE STATION DESIGN
  - 3.1 Modular Configurations
  - 3.2 Radiation Shielding
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  - 3.4 Weight Analysis
  - 3.5 Subsystems
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  - 3.7 Special Subsystem Studies
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## SECTION 4

## PRELIMINARY SPECIFICATIONS

Preliminary model and subsystem specifications for the One and Two Compartment Laboratories, the Interim Station, and the Operational Station are presented in this section. The Apollo and Apollo with the LEM Ascent Stage are not discussed because their specifications are covered in greater depth by their manufacturers.

## 4.1 PRELIMINARY MODEL SPECIFICATIONS

This model specification presents the requirements for the configurations and structure of the Modular Multipurpose Space Station family.

4.1.1 Description

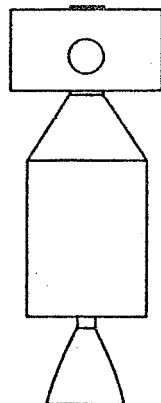
The Modular Multipurpose Space Station study program goal is a family of space stations which are sequentially evolved through progressive subsystem development and structural building blocks, such that a multiplicity of manned missions can be accomplished, each without major changes in hardware concepts. Each of the design concepts is kept free of requirements for technological innovations.

Larger stations are evolved by the addition of structural modules and progressive growth of subsystems leading eventually to an orbital launch facility, semi-permanent orbital space laboratory or other national requirement up to the end of twentieth century.

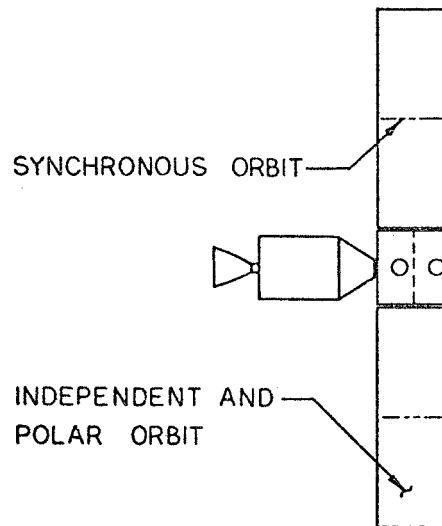
The space station family, as it is envisioned in this preliminary model specification, consists of six space stations evolving from the Apollo Extension System (AES). The four orbital configurations for the six missions that are the subject of this preliminary specification are shown in outline form in Figure 4-1. Pertinent details of the various configurations are given in Table 4-1 and target weights are give in Table 4-2.

Modules for the various stations will be assembled from a few standardized structural elements. These elements include cylindrical body shells of 183 in. diameter and flat circular bulkheads for floors and ceilings.

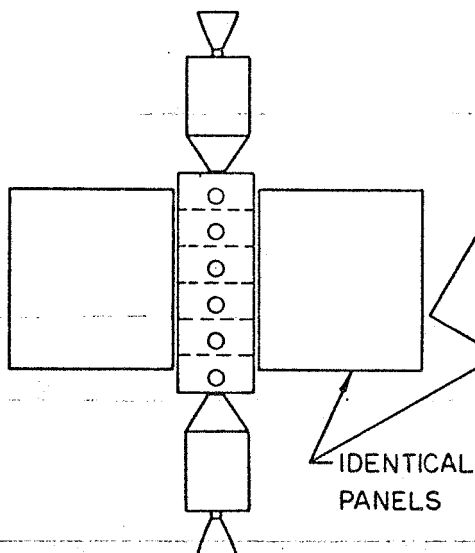
ONE-COMPARTMENT  
DEPENDENT LABORATORY



TWO-COMPARTMENT  
LABORATORIES



INTERIM STATION



OPERATIONAL STATION

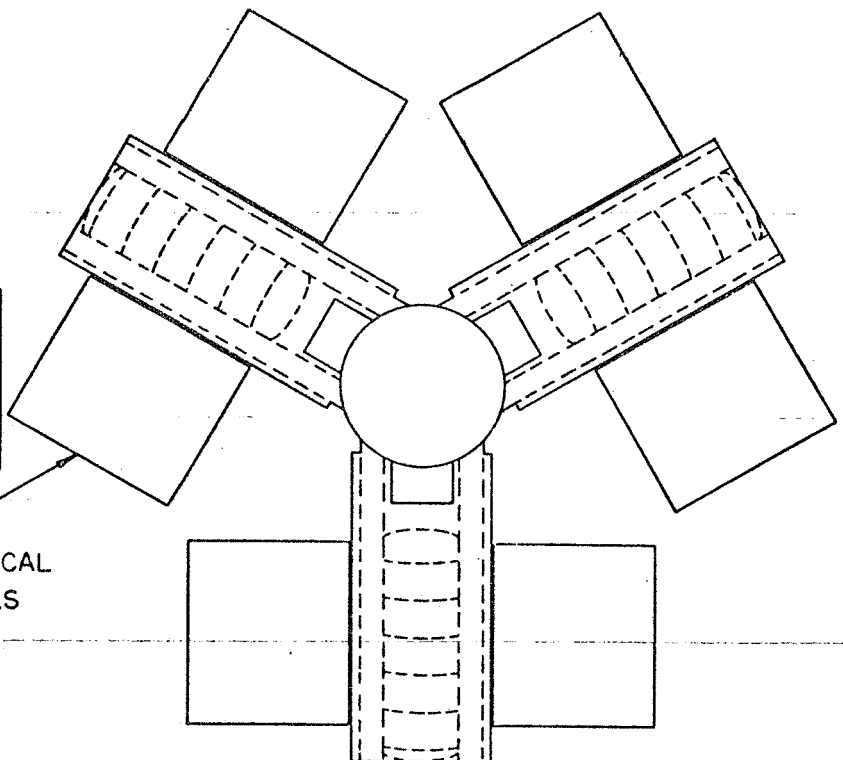


FIG. 4-1. MODULAR MULTIPURPOSE SPACE STATION CONFIGURATIONS

Table 4-1

MODULAR MULTIPURPOSE SPACE STATION CHARACTERISTICS

ITEM	CONFIGURATION	ONE COMPT. DEPENDENT LABORATORY	TWO COMPARTMENT LABORATORIES			INTERIM STATION	OPERATIONAL STATION
			INDEPENDENT	POLAR ORBIT	SYNCHRONOUS ORBIT		
Orbital Altitude, n. miles		200	200	200°	19,380°	200	260
Orbital Inclination		28.5°	28.5°	90°	30°	28.5°	29.5°
Crew Size		3	6	3-6	3-6	6-9	Up to 36
Launch Vehicle		S-IB	S-IB	SV (3-stage)	SV (3-stage)	S-IB	SV (2-stage)
Mission Duration		45 days	Up to 1 Year	90 Days	90 Days	1-5 Years	5-10 Years
Crew Orbital Duration		45 Days	6 Months	90 Days	90 Days	6 Months	6 Months
Resupply Period		None	3 Months	None	None	3 Months	3 Months
Manned at Launch		Yes	Yes	Yes	Yes	No	No
Diameter of Compartment		183"	183"	183"	183"	183"	183"
Floor Pitch		N/A	90°	90°	90°	90°	90°
Floor Radius (Cylindrical)		Flat	Flat	Flat	Flat	Flat	717.5"
Structure		Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Meteoroid Shielding							
Airlock Provisions		Yes	Yes	Yes	Yes	Yes	Yes
Leakage Rate		8 lb/Day	7 lb/Day	7 lb/Day	7 lb/Day	10 lb/Day	24 lb/Day
Living and Sleeping Space		Apollo	Yes	Yes	Yes	Yes	Yes
Docking Provisions		Yes	Yes	Yes	Yes	Yes	Yes
Electric Power Source		Fuel Cell	Solar Cells	Solar Cells	Solar Cells	Solar Cells	Solar Cells
Power Level		1.5 kw	5-10 kw	5-10 kw	5-10 kw	10 kw	30 kw
Power Source Evolution		None	Isotope	Isotope	Isotope	Nuclear	Nuclear
ECS & Life Support		Open	Partially	Partially	Partially	Partially	Partially
Environmental Req.		Pressure Suit/ Shirtsleeve	Pressure Suit/ Shirtsleeve	Shirtsleeve	Shirtsleeve	Shirtsleeve	Shirtsleeve
Atmospheric Constituency		O <sub>2</sub>	O <sub>2</sub> /N <sub>2</sub>	O <sub>2</sub> /N <sub>2</sub>	O <sub>2</sub> /N <sub>2</sub>	O <sub>2</sub> /N <sub>2</sub>	O <sub>2</sub> /N <sub>2</sub>
Pressure Level, Total		5 psi	7 psi	7 psi	7 psi	7 psi	3 1/2 to 14 psi

.99 PROBABILITY OF NOT MORE THAN ONE PENETRATION PER MONTH

Table 4-2

SUMMARY WEIGHT DATA, MODULAR MULTIPURPOSE SPACE STATIONS

I T E M	ONE COMPT. DEPENDENT LABORATORY	TWO COMPARTMENT LABORATORIES			INTERIM STATION	OPERATIONAL STATION
		INDEPENDENT	POLAR ORBIT	SYNCHRONOUS ORBIT		
Laboratory Subsystems, Dry	5,400	12,730	14,110	12,400	26,510	160,210
Structure	2,810	4,480	4,480	4,480	10,480	107,660
Environmental Control	700	1,270	1,270	1,270	2,450	9,400
Electrical Power	1,440	3,200	3,200	1,800	7,620	20,640
Reaction Control	--	180	--	--	330	1,150
Communications	10	380	380	380	1,170	2,210
Data Management	60	180	180	140	230	580
Navigation and Guidance	10	300	330	280	230	300
Stabilization and Control	--	370	380	50	690	5,000
Display Panels & Instrumentation	150	230	230	230	460	1,830
Crew Provisions, Furnish., & Trim	220	1,340	1,340	1,340	1,650	6,600
Radiation Shield Provisions	--	800	2,320	2,430	1,200	4,840
LEM Adapter	3,500	3,500	3,500	3,500	--	--
Apollo Command & Service Module	16,690	15,950	15,730	16,230	--	--
Propellant	2,500	2,500	1,500	16,000	--	--
Fairings, Jettisoned					1,830	1,200
Laboratory Start-up Provisions					1,160	4,650
Orbit Injection Fuel & Tanks					1,700	--
Orbit Injection Syst., Fuel & Tanks					--	8,700
Discretionary Payload*	8,710	2,120	6,160	14,870	5,600	72,740
Effective Launch Capability	36,800	36,800	41,000	63,000	36,800	247,500

\*Discretionary payload includes mission consumables, containers, spares, and experimental equipment

One-compartment modules will be assembled from a single cylindrical shell member plus two flat end bulkheads. Larger modules, up to and including the Interim Station, will be constructed by welding additional cylindrical body shells together and capping them with flat end bulkheads. Each body shell piece will have a flat circular floor for uniformity of design and fabrication. The Operational Station modules will utilize the cylindrical body shells but the flat end plates will be replaced with elliptical end domes and the floors will be curved cylindrically. Module structural details may be seen in Figure 4-2. Single and two compartment modules are shown in Figure 4-3 and -4 respectively. Compartmenting details of the stations are summarized in Table 4-3.

The cylindrical body shells and flat end bulkheads will be equipped with universal hatches (See Figure 4-5) which can serve as docking ports, windows, access tube connections, or external locks for experimental or cargo packages. The elliptical end domes of the Operational Station do not incorporate the universal hatches.

The coordinate systems to be used for the space stations shall be as follows:

- The X-axis lies along the centerline of the launch configuration, positive in the launch direction.
- The Y-axis passes through the universal ports in the lowermost compartments.
- The Z-axis is mutually perpendicular to the X and Y axes to form a right-hand coordinate system.

The Operational Station will be solar oriented; all other stations of the family will be earth oriented with the X-axis parallel to the surface of the earth.

#### 4.1.2 Performance Requirements

The Modular Multipurpose Space Stations shall meet the requirements specified in Table 4-1.

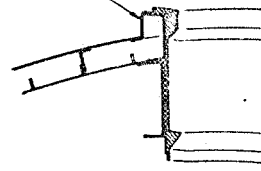


Table 4-3  
COMPARTMENTATION SUMMARY

<u>Station</u>	<u>No. of Modules</u>	<u>Compartments per Module</u>	<u>Floors</u>	<u>End Plates</u>
One Compartment Laboratory	1	1	Flat	Flat
Two Compartment Independent Laboratory	1	2	Flat	Flat
Two Compartment Polar Orbit Laboratory	1	2	Flat	Flat
Two Compartment Synchronous Orbit Laboratory	1	2	Flat	Flat
Interim Station	1	6	Flat	Flat
Operational Station	3	6	Curved	Elliptical



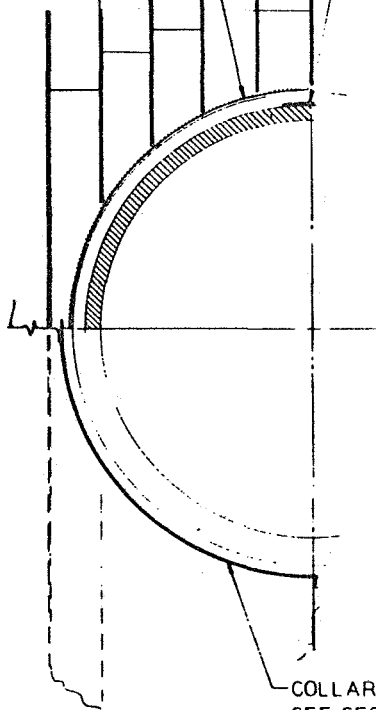
.040 COLLAR



INSULATION RETAINING SPRING

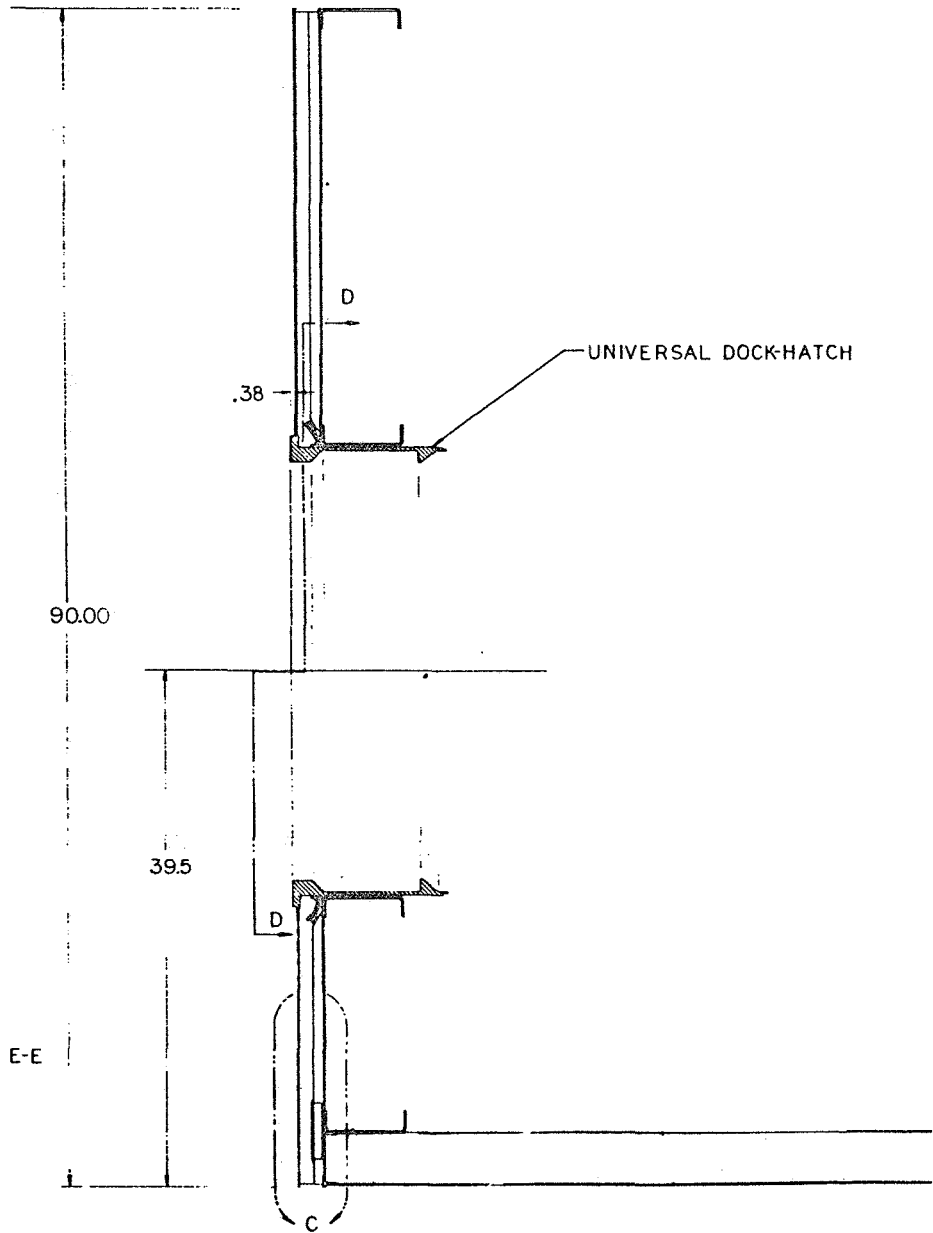
PRESSURE SKIN

WELD ALL AROUND



COLLAR  
SEE SECTION E-E

SECTION D-D

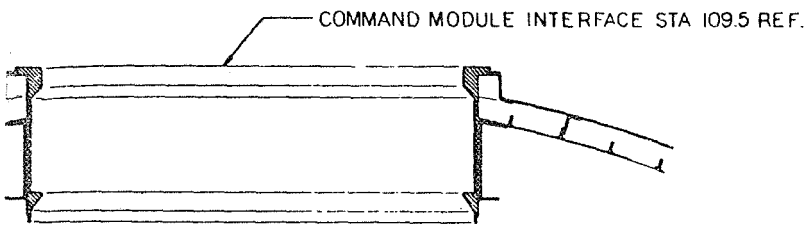


UNIVERSAL DOCK-HATCH

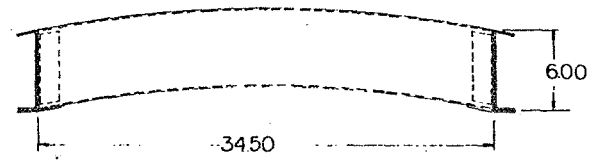
39.5

D

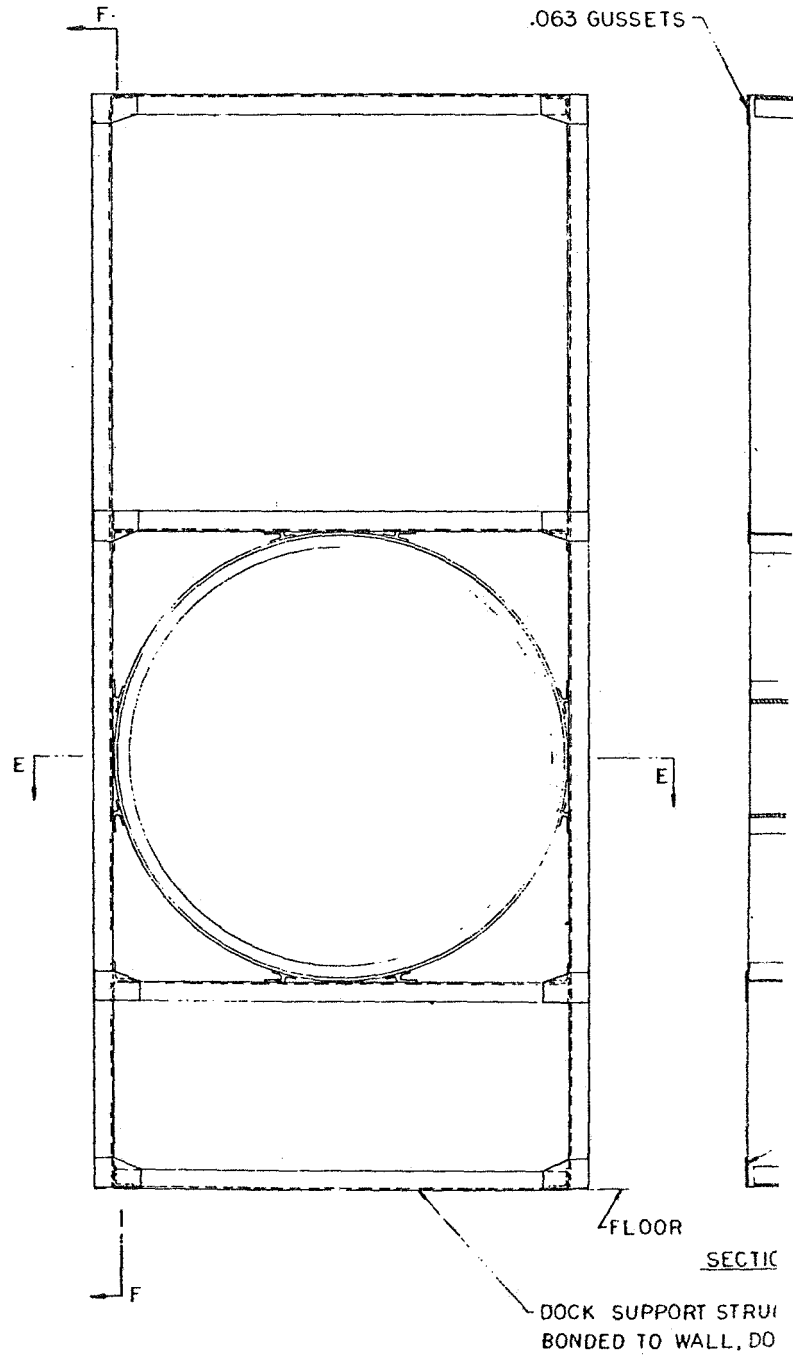
C



SECTION E-E

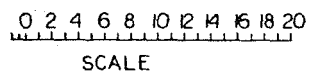


.063 GUSSETS

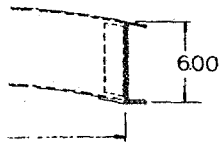


PRÉSSURE FLOOR

SECTION A-A



SECTION B-B



.063 GUSSETS

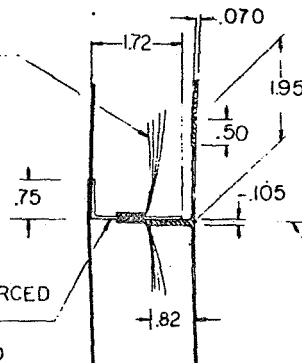
MYLAR INSULATION  
24 LAYERS

.050 FIBER REINFORCED  
PLASTIC  
TYP. EVERY THIRD  
STIFFENER (48 PLACES)

.063 CLIPS

.070 BEAMS

CONVENTIONAL RIVET ASSY.



LONGITUDINAL WELD SEAM  
TYP. EVERY SIXTH STIFFENER (24 PLACES)

REF LINE  
TYP. EA. 25° (144 PLACES)

E

FLOOR

SECTION F-F

DOCK SUPPORT STRUCTURE  
BONDED TO WALL, DOCK & FLOOR

AM  
FENER (24 PLACES)

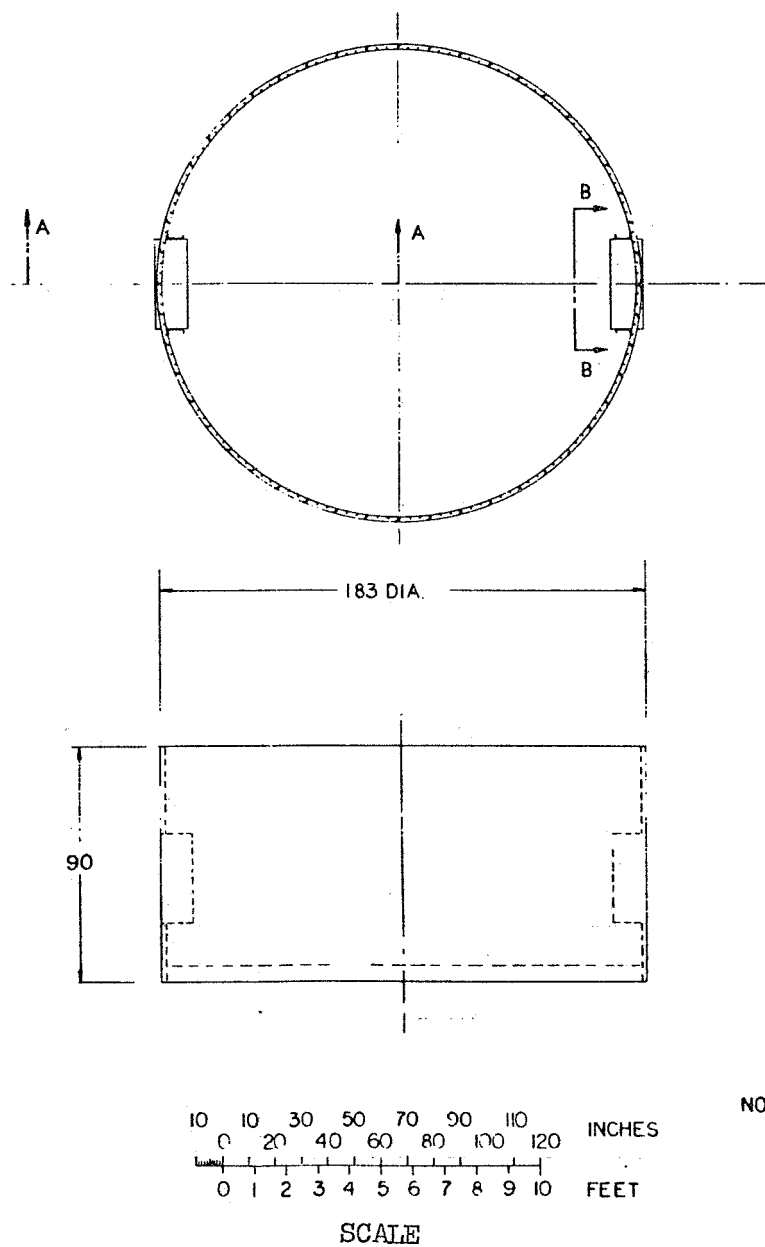
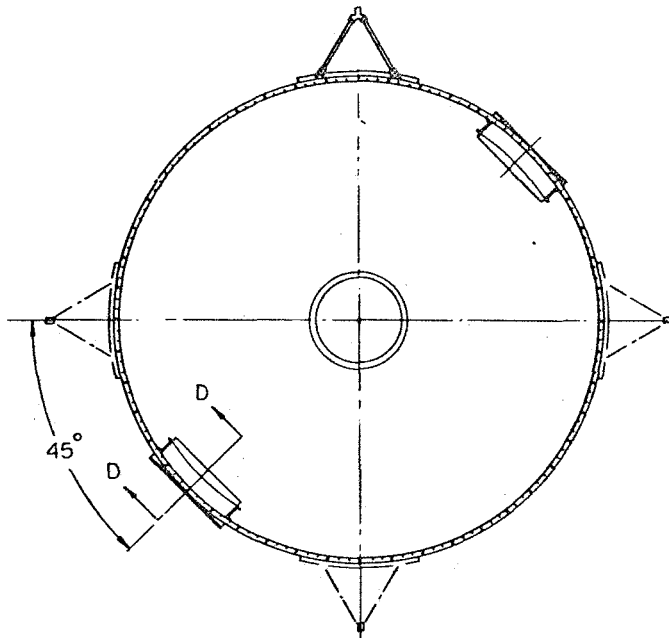


FIG. 4-2 STRUCTURAL DETAILS, MODULAR CONCEPT

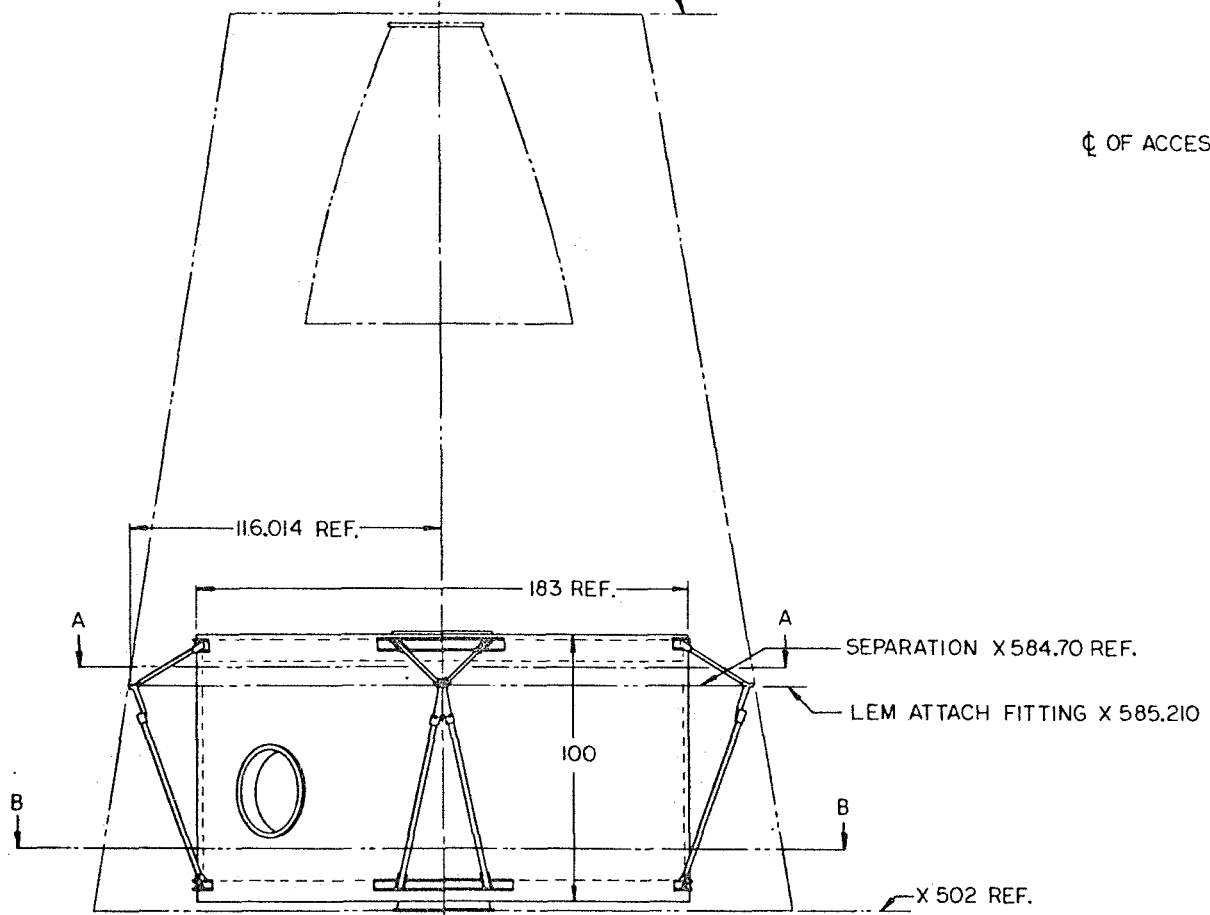




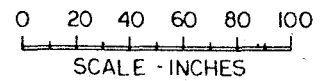
VIEW A-A

X 838, X<sub>S</sub> 200, LEM 438.50 REF.

Ø OF ACCESS PORTS



INSTALLATION IN STANDARD LEM ADAPTER



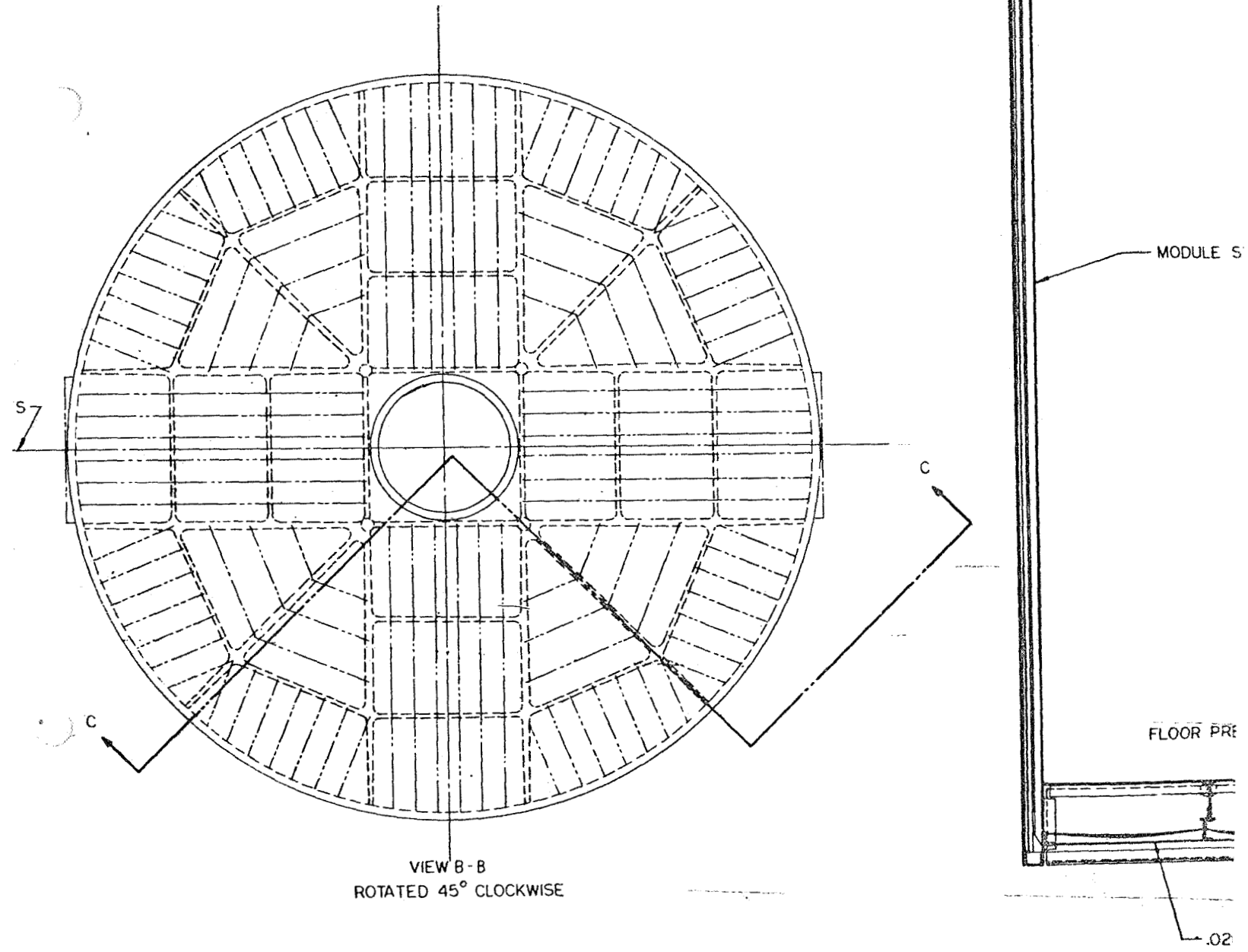
.020 METEOROID BUMPER

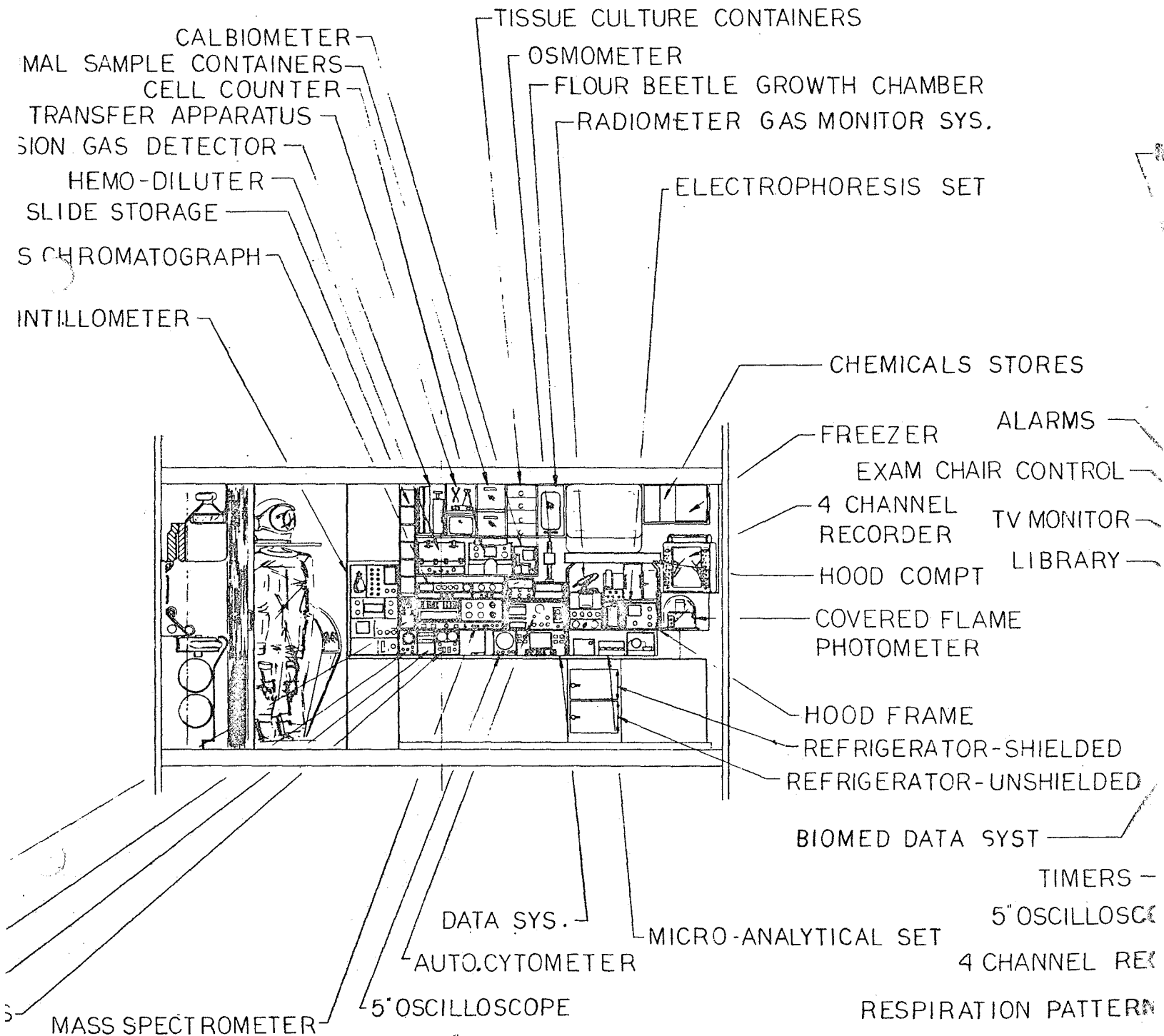
MODULE S

FLOOR PRE

.02

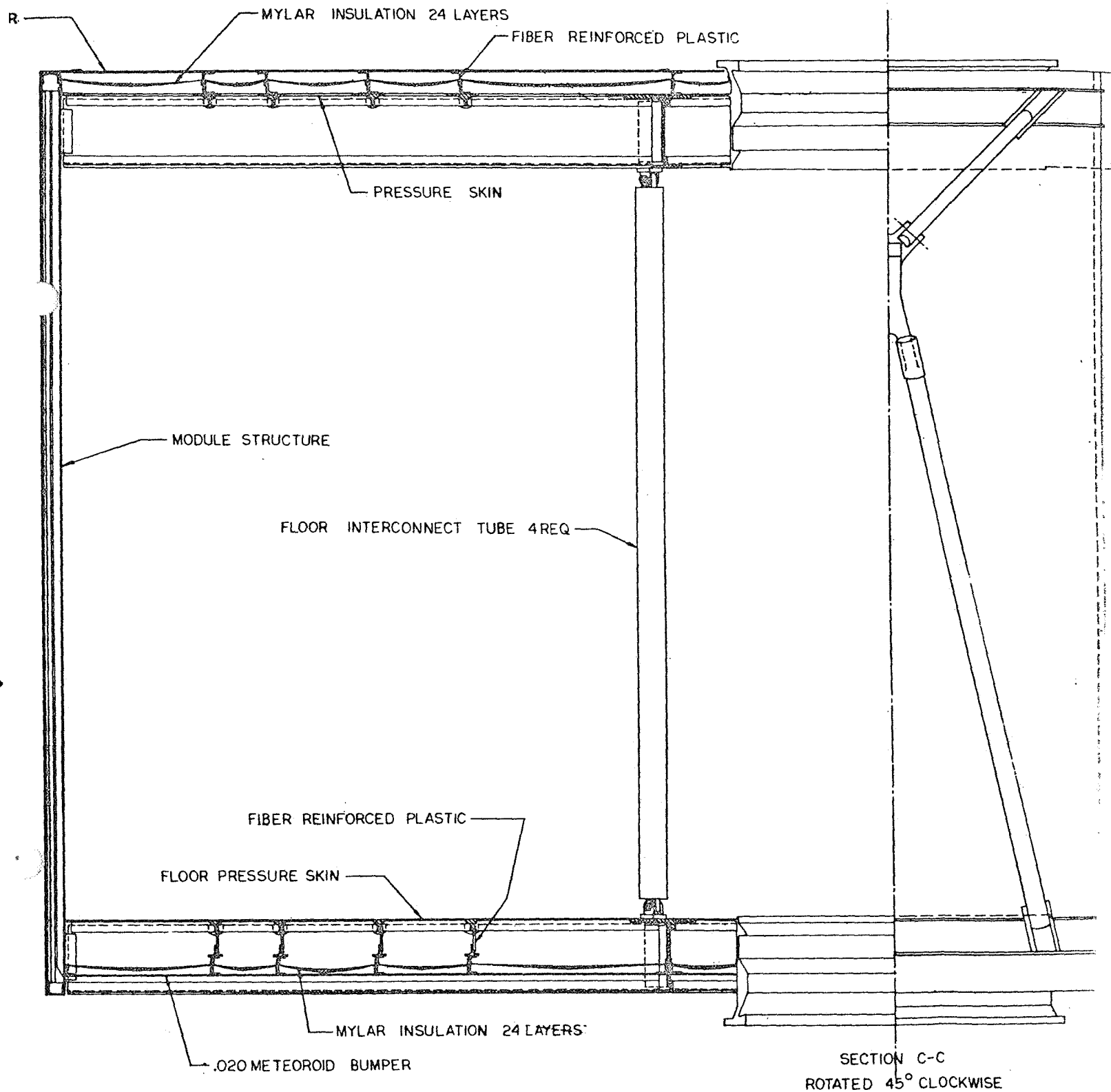
VIEW B-B  
ROTATED 45° CLOCKWISE

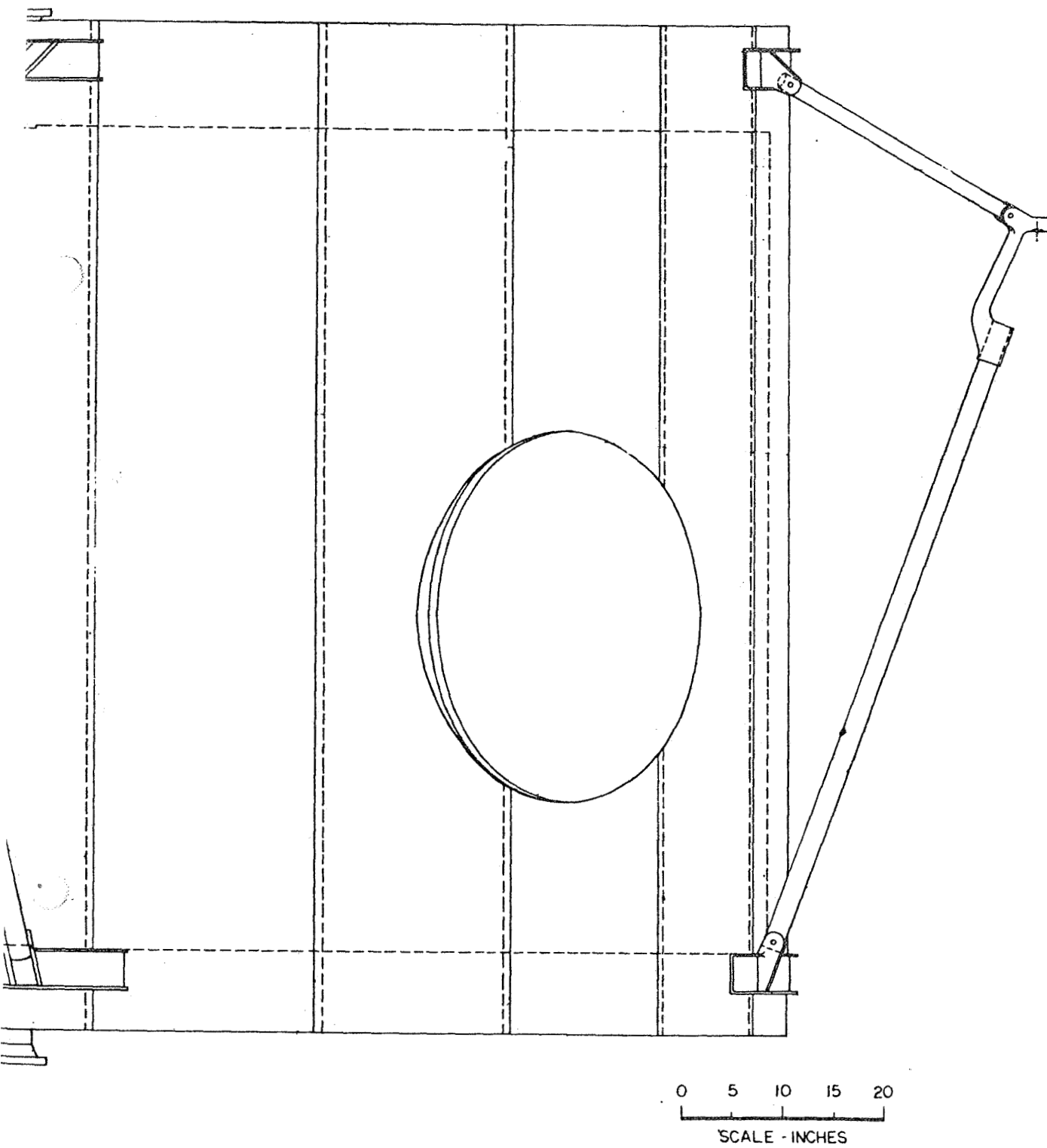




SECTION C-C  
 LABORATORY AREA

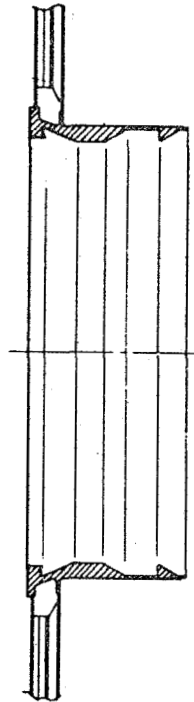
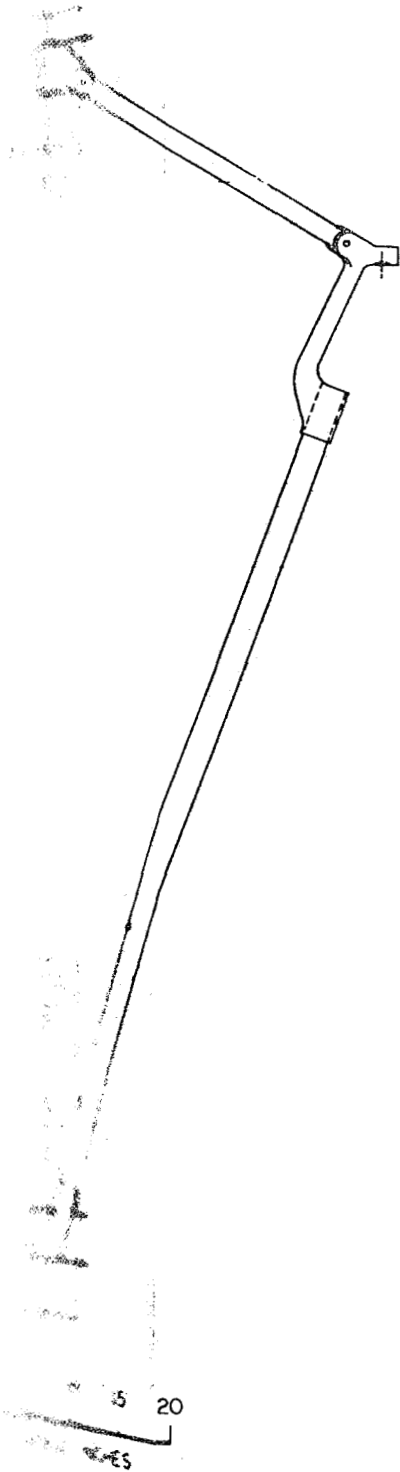






5  
ROTATE

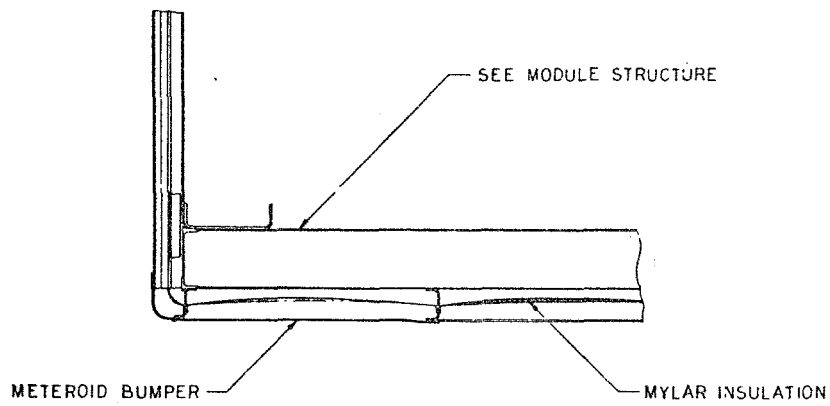
FIG. 4-3 ONE-COMPARTMENT LABORATORY ASS



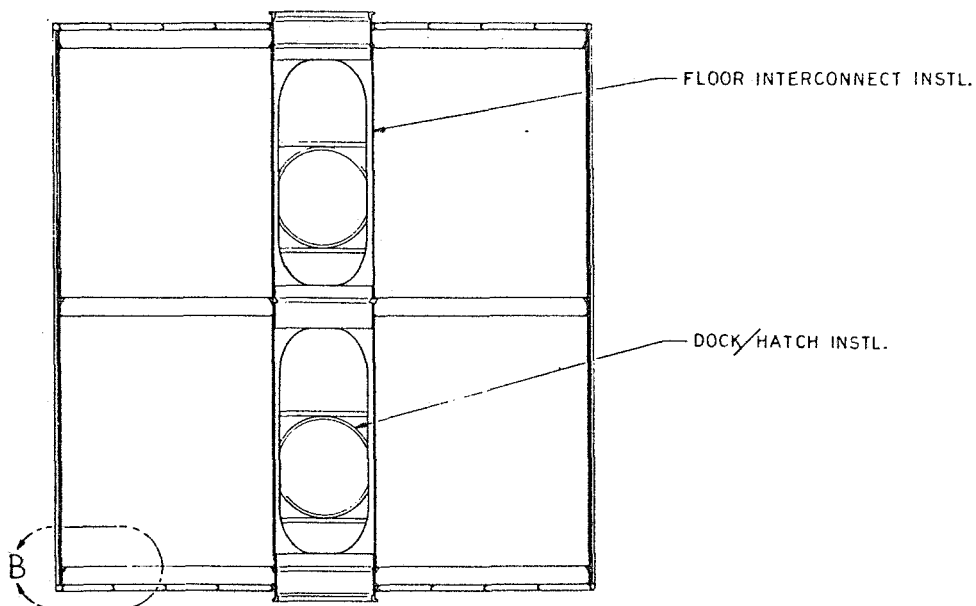
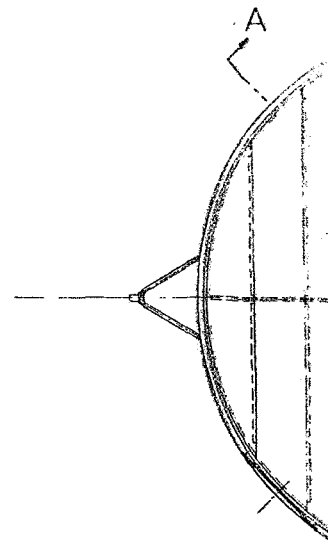
SECTION D-D  
SIDEWALL HATCH  
ROTATED 45° CLOCKWISE

ONE-COMPARTMENT LABORATORY ASSEMBLY, BEAM FLOOR

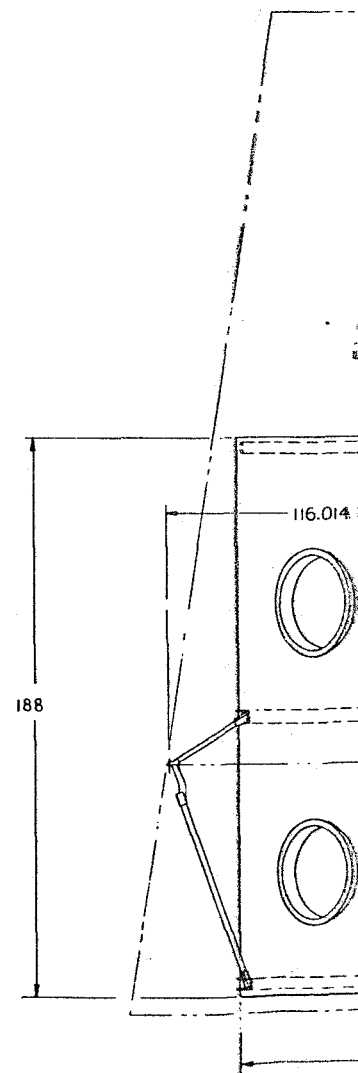
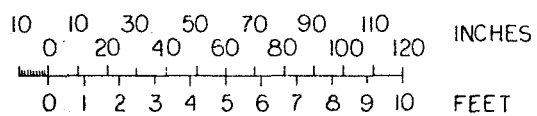




DETAIL - B



SECTION A - A



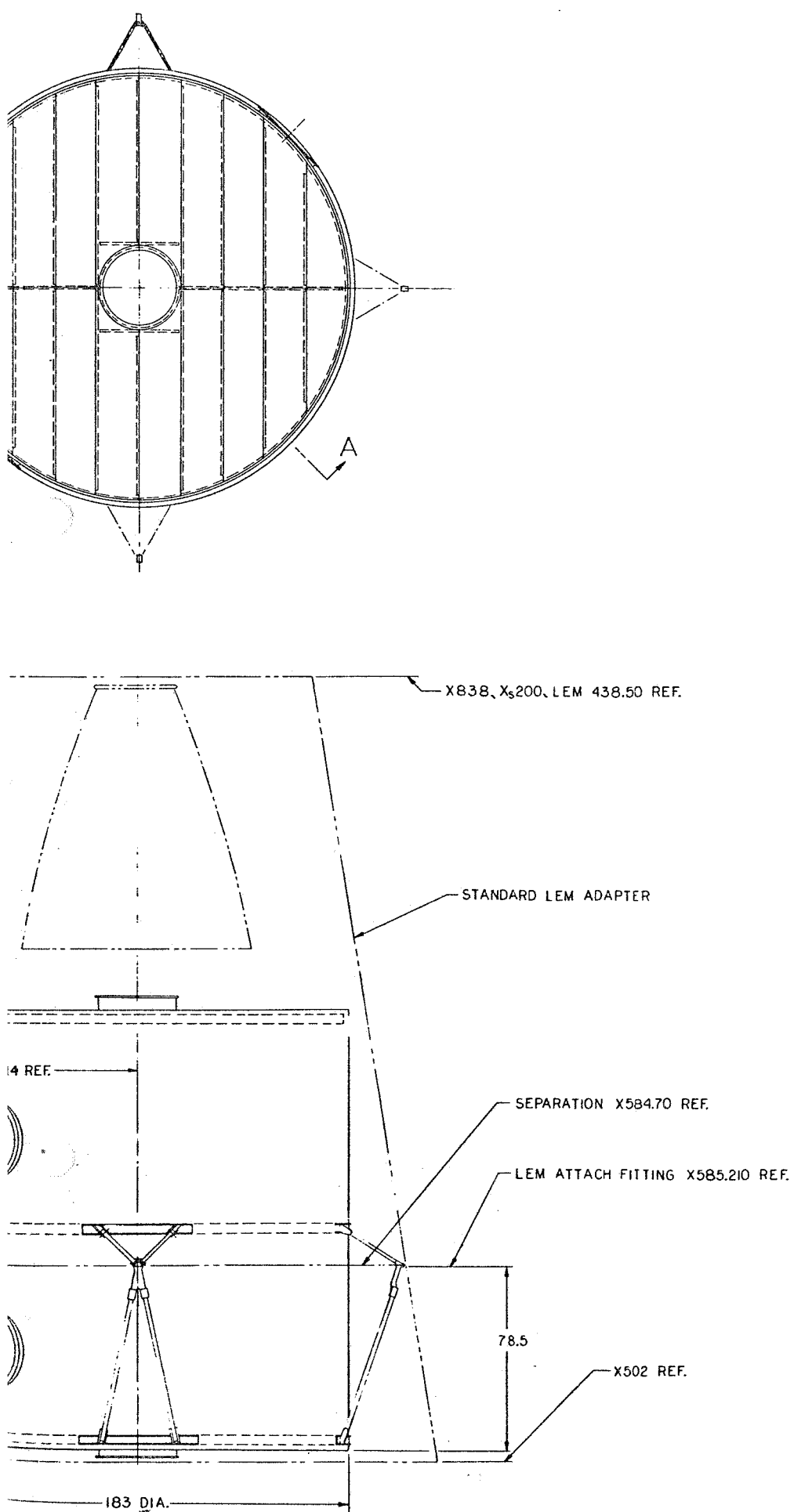
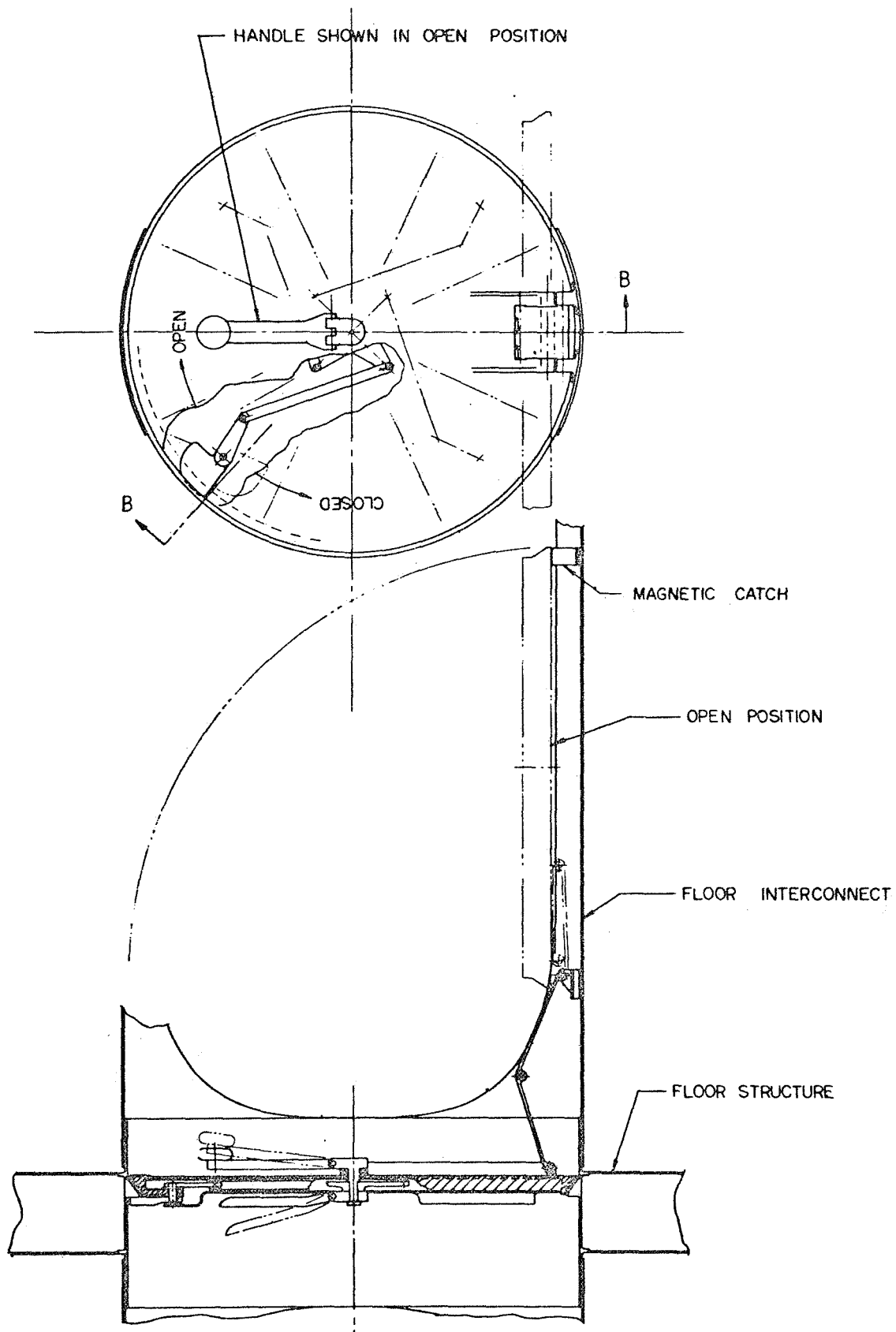


FIG. 4- 4 TWO-COMPARTMENT LABORATORY ASSEMBLY





EXTERNAL  
OR EXTERN

INTER-COMPARTMENT HATCH  
SECTION B-B



EXTERNAL EXPERIMENT PACKAGE  
OR EXTERNAL LOCK

WINDOW INSTALLATION

ALTERNATE USES OF TYPICAL  
EXTERNAL HATCH

DOCKING PROBE

APOLLO LOGISTICS  
VEHICLE

HATCH

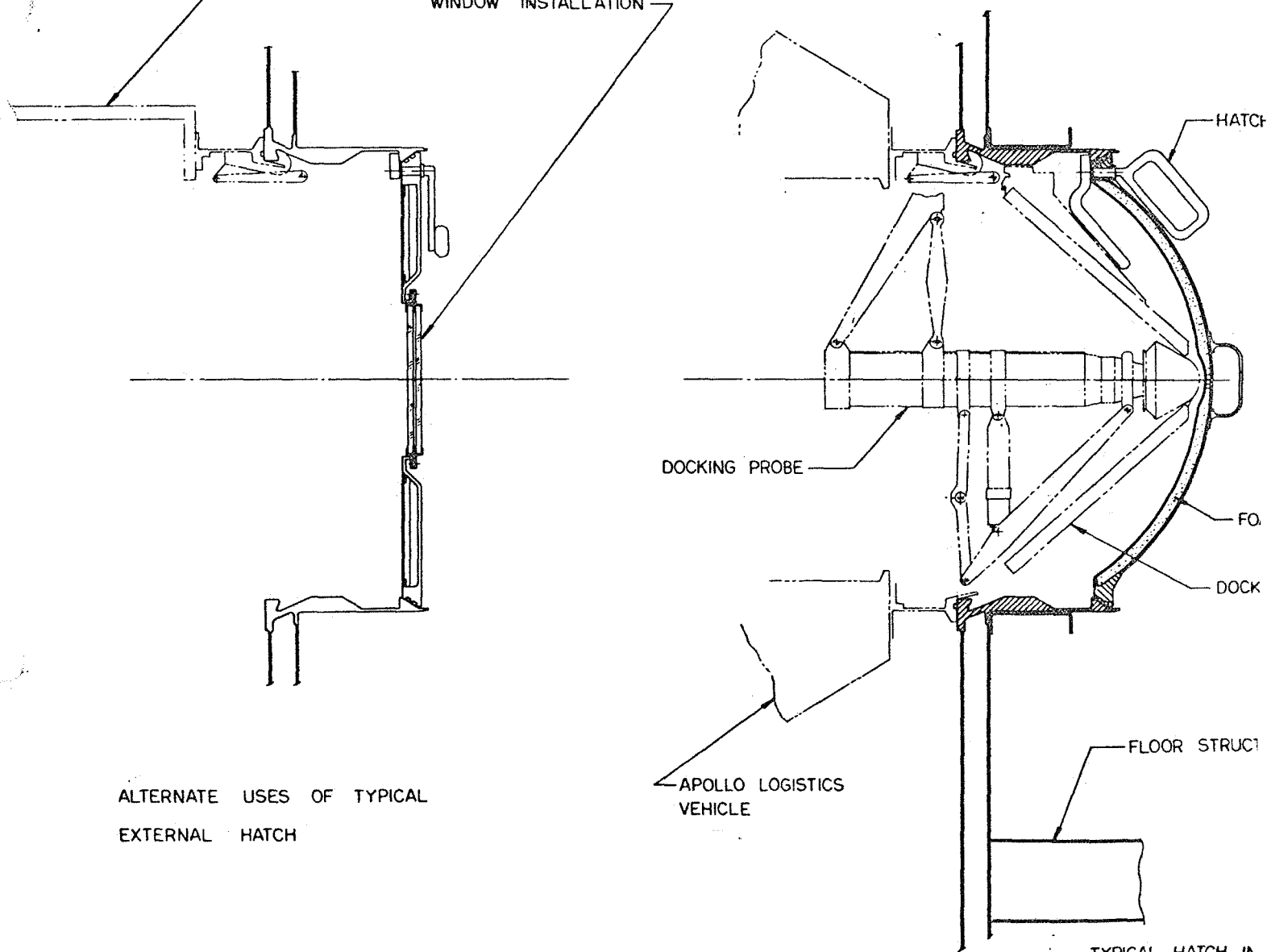
FO

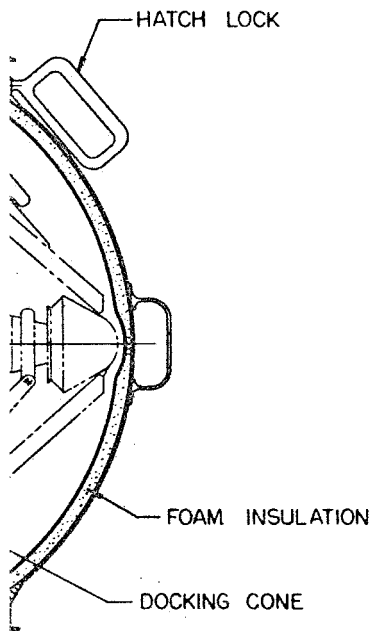
DOCK

FLOOR STRUCT

TYPICAL HATCH IN  
OF MODULE

SECTION A-A



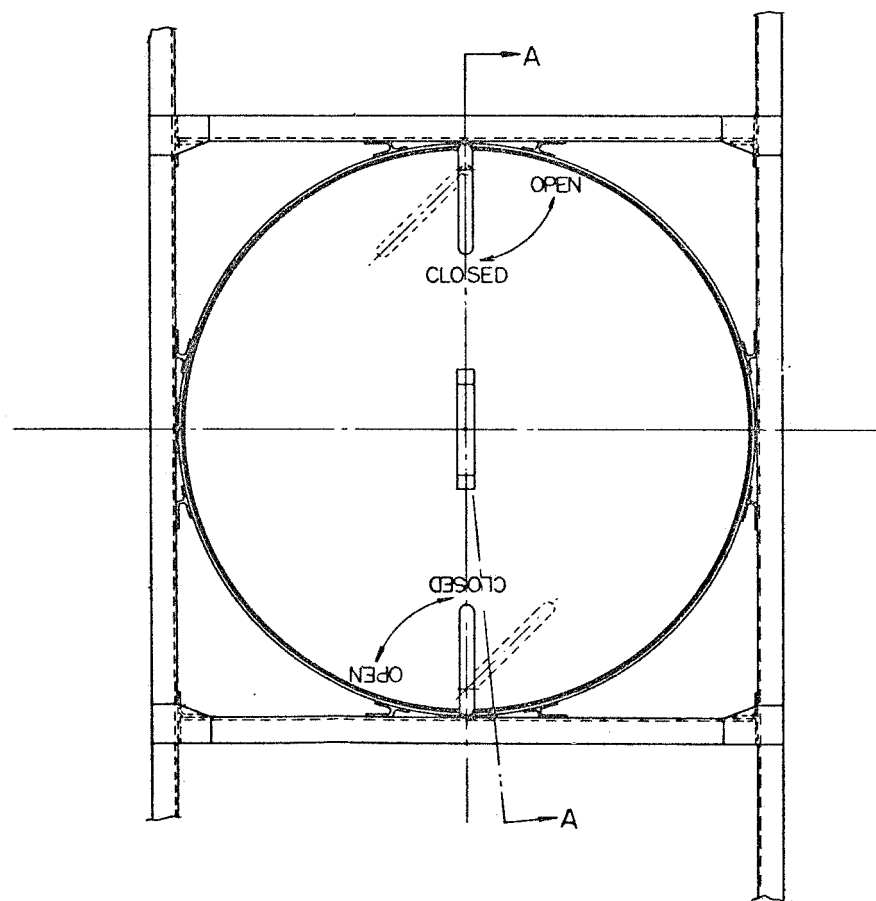


—FLOOR STRUCTURE



TYPICAL HATCH IN SIDES & ENDS  
MODULE

-A



TYPICAL HATCH

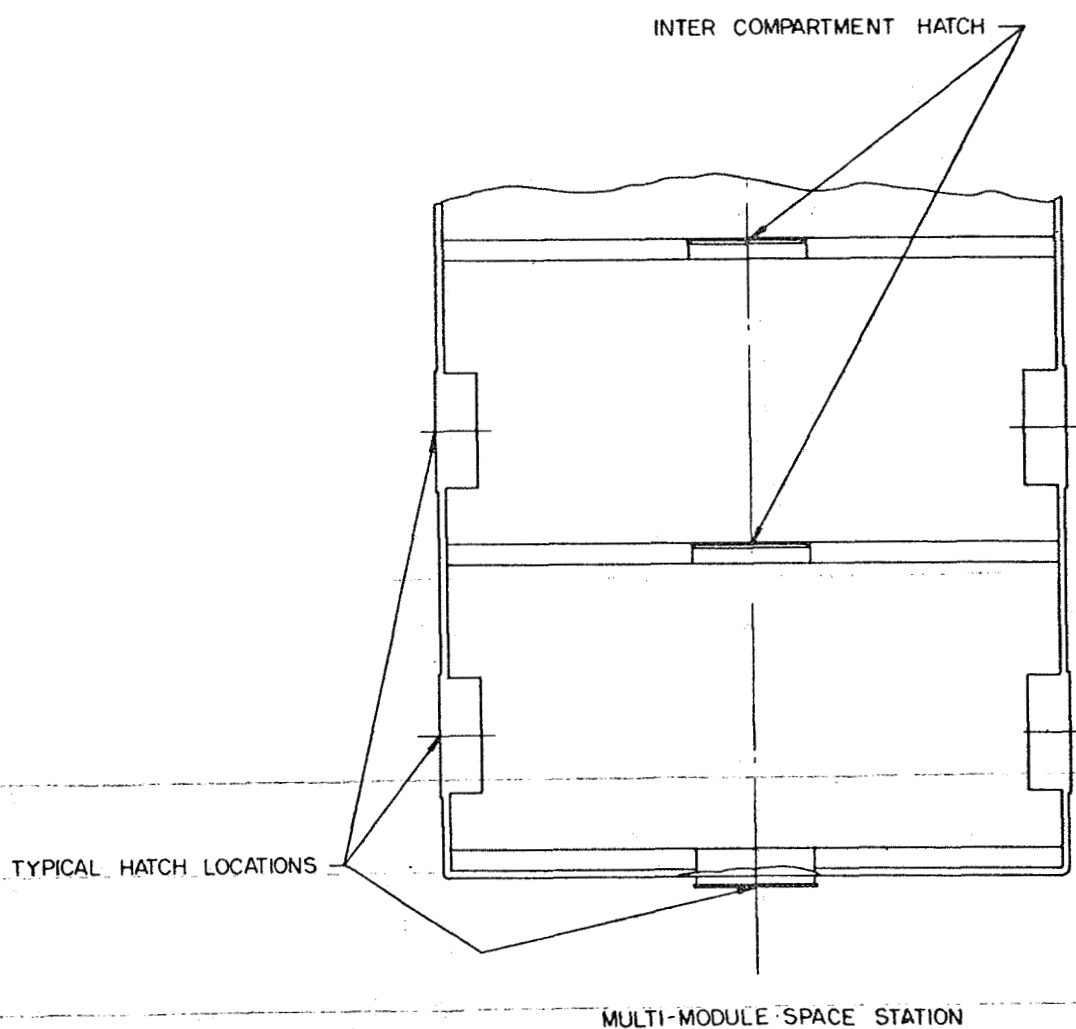


FIG. 4-5. UNIVERSAL HATCH, TYPICAL APPLICATION



#### 4.1.3 Design Requirements

##### General

The stations shall conform as nearly as possible to Figure 4-1. The target weights given in Table 4-2 shall be goals. Physical details shall meet the requirements of Table 4-1.

The modules for the stations shall be designed in accordance with the principles and dimensions given in Figure 4-2. Universal hatches shall be utilized in the design of the modules as shown in Figures 4-2 and 4-5.

The stations, subsystems and furnishings shall be functional and appropriate for zero-gravity environment. In addition, the Operational Station shall be suitable for partial gravity.

Conservative design practices shall be followed so that requirements for advances in state-of-the-art will be minimized. Design flexibility shall be maintained so that advantage can be taken of technological advances that may appear prior to initiation of detail design. Simplicity in design of the stations shall be emphasized. Station abandonment and mission abort are not to impose design compromises; the stations are to accommodate all but the most improbable hazards.

Equipment placement within the stations shall permit repairs to the pressure walls, minimize coriolis effects in rotational modes of operation and maximize radiation protection.

The designs shall be functionally suitable for any necessary extra-vehicular activities, such as the inspection and replacement of solar cells and the maintenance of external hatches and seals. Hatch/door dimensions shall be adequate to permit unimpeded passage of personnel, and all airlock doors shall normally remain closed.

The stations shall be designed so as to meet the mission requirements of Table 4-1.

The stations shall be designed to use existing facilities and checkout equipment wherever possible. Wherever feasible, the stations and their subsystems shall be designed so that maintenance and repair can be accomplished without any tools. The use of special tools and test fixtures shall be minimized.

#### Structural Design

Factor of Safety - The factor of safety for all primary structure (pressure vessels excluded) shall be 1.5. The stress in any element of the structure when subjected to ultimate load shall not exceed the allowable stress of the material.

Pressure Vessels. Pressure vessels shall be designed to the following factors:

- Cabin and Pressurized Compartments  
Pressure acting alone:  
Limit Pressure =  $1.33 \times \text{Max. Operating Pressure}$   
Ultimate Pressure =  $2.00 \times \text{Max. Operating Pressure}$
- Fluid Tanks:  
Limit Pressure =  $1.33 \times \text{Max. Operating Pressure}$   
Ultimate Pressure =  $2.00 \times \text{Max. Operating Pressure}$
- Module Floors:  
Limit Pressure =  $\text{Max. Operating Pressure}$   
Ultimate Pressure =  $2.00 \times \text{Max. Operating Pressure}$
- Maximum Operating Pressures:  
Cabin and compartments.....14.7 psi  
Floors..... 7.0 psi  
Fuel Tanks..... To be determined

Design docking loads shall be based on the following docking parameters:

Relative Axial Velocity, 2 ft/sec  
Relative Lateral Velocity, 1 ft/sec  
Relative Angular Velocity, 1 deg/sec  
Lateral Misalignment, 1-ft  
Angular Misalignment, 10 deg

To account for dynamic effects, the exit flight loads shall include a factor of 1.20 and the prelaunch and launch loads shall include a factor of 1.15.

Exit loads shall be based on launch vehicle compatibility with payload weight and external shape. The nominal exit trajectory shall be combined with the non-dimensionalized wind profile shown in Figure 4-6. The maximum wind velocity shall be chosen to give loads just equal to the permissible values at the critical interface joint between launch vehicle and payload.

#### Launch Criteria

The stations shall be launched from the Eastern Test Range.

The stations shall be compatible with existing launch facilities.

The stations shall be designed to be launched by the vehicles indicated in Table 4-1.

Launch capability shall be determined from Figure 4-7 using the maximum wind velocity corresponding to launch vehicle strength capability. The launch phase is defined as the time from removal of the gantry until the pitch-over to trajectory flight.

The vehicle shall be capable of sustaining the 95 per cent probability wind as shown in Figure 4-8.

The Interim and Operational Stations shall be launched unmanned. The other stations will be launched manned.

#### Environmental Criteria

Meteoroid Protection. The design data for meteoroid environment and penetration shall be in compliance with NASA-MSC Engineering Criteria Bulletin, Serial No. EC-1, dated 8 November 1963, except that the flux ratio shall be 1.0 for all shower particles of mass less than  $10^{-2}$  gram. Summer's modified equation for finite metallic sheets shall be used in all meteoroid penetration calculations.

The radiation environment to be used as a basis for design shall be as discussed in Section 3.2 of this report and Section 3 of Lockheed Report No. LR 17502. The allowable radiation dosage limits for the crew shall be as defined by the NASA:

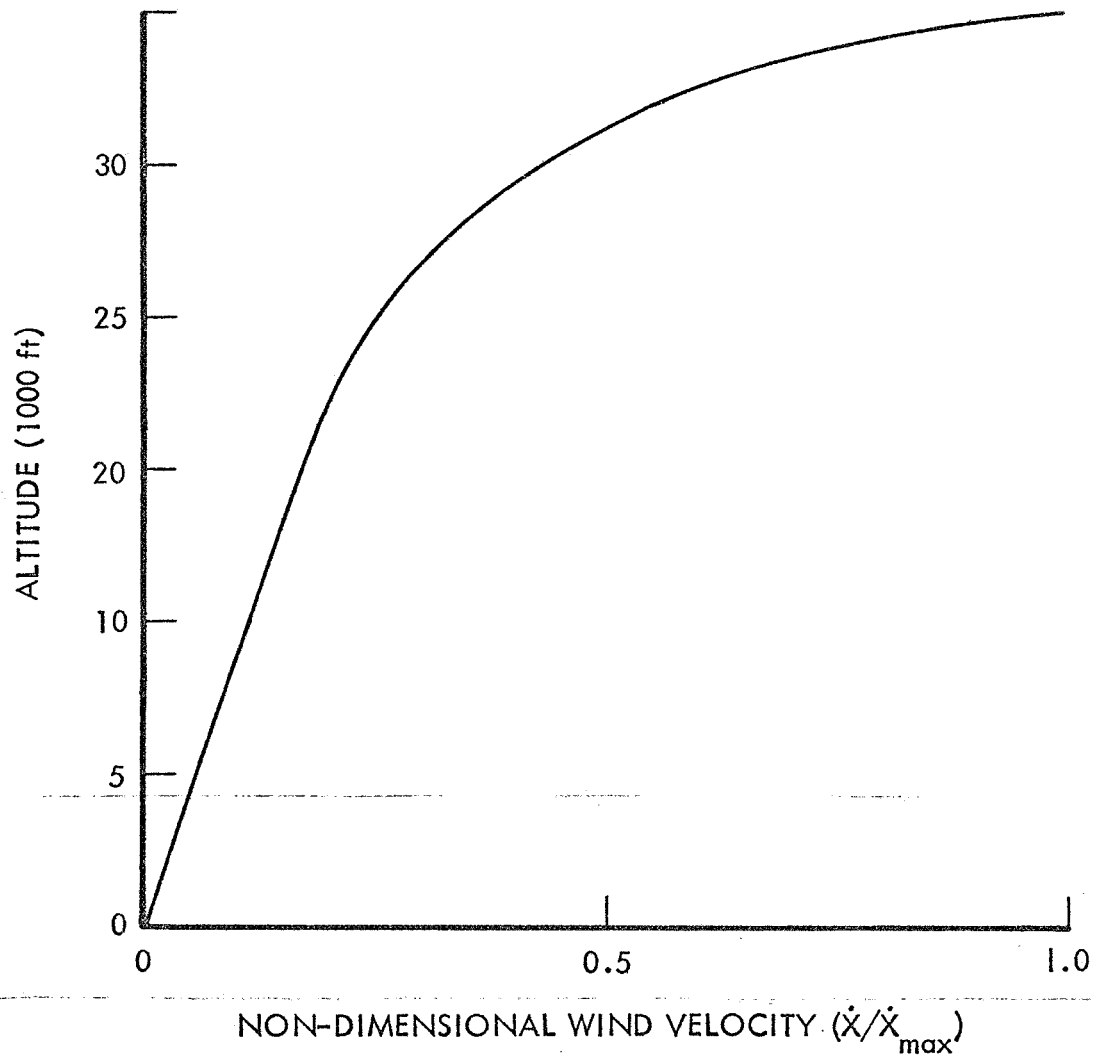


FIG. 4-6 DESIGN WIND PROFILE



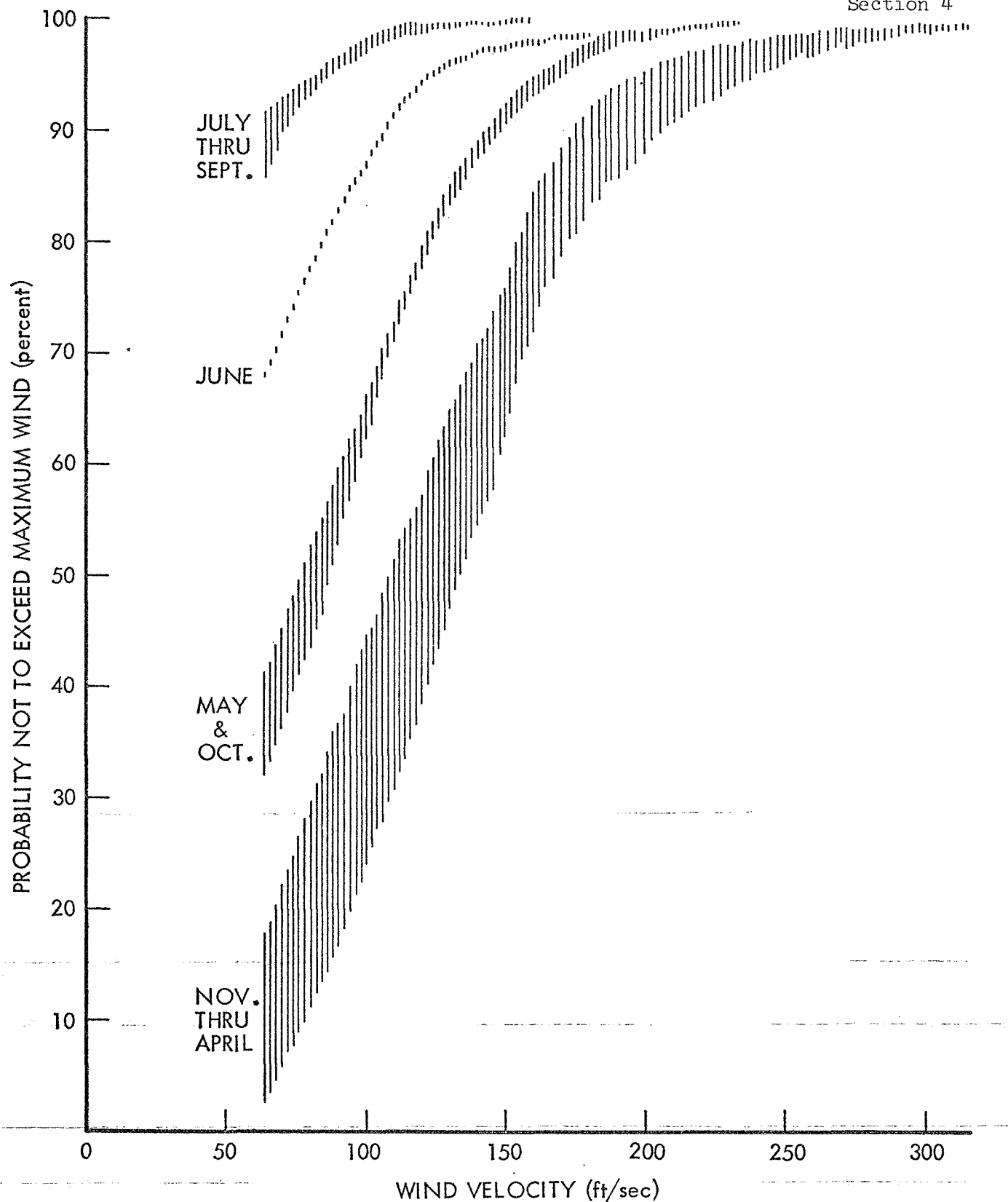


FIG. 4-7 PROBABILITY OF OCCURRENCE OF MAXIMUM WIND SPEEDS AT PATRICK A.F. BASE

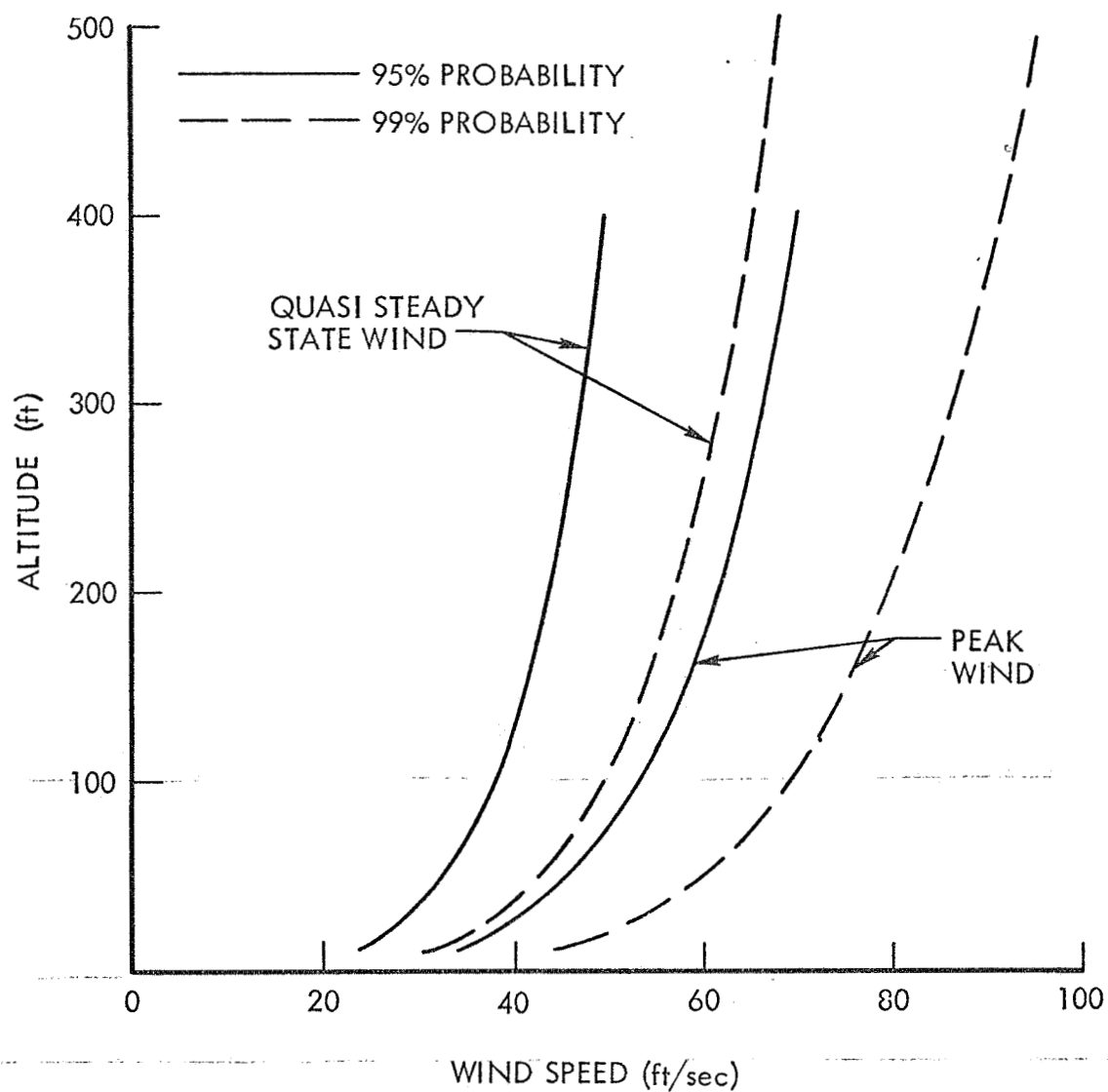


FIG. 4-8 GROUND SPEED WIND ENVELOPE FOR 99% & 95% PROBABILITY OF OCCURRENCE

<u>Critical Body Organ</u>	<u>Average Yearly Dose (Rad.)</u>
Eyes	27
Blood forming organs	54
Feet, ankles, and hands	559
Skin of whole body	233

#### Crew Criteria

The station designs shall be suitable for personnel within the range of physical measurements of the 10th to the 90th percentile, based on Air Force flight personnel.

The station designs shall include provisions for docking or hangaring sufficient logistic spacecraft to evacuate the entire crew at any time during the mission.

The crew quarters (where applicable) shall be designed to give privacy to personnel.

The station designs shall include crew locomotion aids for zero gravity operation. Sharp corners on equipment shall be avoided and padding of exposed surfaces shall be considered. Exposed knobs, switches, etc., shall be recessed if possible.

The crew seats, bunks, etc., on those stations having artificial gravity capability shall be designed and oriented to minimize coriolis effects.

Life lines, anchor points and umbilical connections shall be provided for extravehicular activities.

#### Emergencies

The station designs shall permit 100 per cent abort capability for the crews at all times.

~~The space stations shall be designed to accommodate emergencies; rapid~~  
egress is not a primary design constraint. Specific design requirements to neutralize emergencies are:

Place equipment so that external walls are accessible for the repair of punctures.

- Design equipment and structures with fail safe features.
- Provide fire control techniques.
- Provide manual backup for automatic subsystem operations.
- Provide readily accessible pressure suits and back packs.
- Incorporate cooling provisions, other than air, in equipment that must operate under decompressed conditions.

#### Cargo

The transfer of liquids between the logistic vehicles and the stations shall be by pipeline rather than by portable tanks. Transfer of gases shall be by portable tankage.

Solid cargo packages shall be limited to a maximum size of 28 inches diameter by 40 inches length.

#### Logistics

Logistic requirements shall be based on the resupply periods shown in Table 4-1.

The docking operations shall normally be under the control of the logistic spacecraft with space station cognizance. Docking mechanisms, hatch covers, and pressure controls for airlock operation shall normally be controlled by space station personnel but provisions shall be made to allow control by logistic spacecraft personnel.

#### Maintenance

The stations shall be designed to permit repair and maintenance of exterior components such as solar array panels, antennas, etc.

Interior arrangements shall allow access for the repair of punctures and cracks in the walls.

Equipment shall be designed to minimize the number and complexity of maintenance tasks.

Wherever possible, the need for maintenance tools shall be eliminated. Maintenance tools, if essential, shall be located conveniently close to the pertinent components.

#### 4.2 PRELIMINARY SUBSYSTEM SPECIFICATIONS

Performance and design requirements for the subsystems of the Modular Multipurpose Space Station family are presented in this section. The requirements are stated only for new concepts or modified Apollo subsystems; unmodified Apollo subsystem requirements are not presented. The majority of the requirements are specific in nature, i.e., they apply to particular subsystems or space stations; these are presented in paragraphs 4.2.1 through 4.2.7. There are a number of requirements, however, which apply to all subsystems and space stations and these are listed below.

##### General Requirements

- All components and subsystems shall be suitable for sustained zero gravity operation.
- Subsystems shall be modularized wherever possible. Commonality of subsystems and components shall be emphasized.
- Apollo-type and other existing hardware shall be used whenever possible, provided that mission success is in no way jeopardized.
- High reliability shall be sought throughout the program. In attainment of this goal, the use of high quality products will be emphasized. New techniques, such as microminiaturization of electronic equipment, will be employed.
- All subsystem components shall be designed and installed so that they are accessible for maintenance and repair. Conservative design practices shall be followed so that requirements for advances in the state-of-the-art will be minimized.

##### 4.2.1 Environmental Control and Life Support Subsystem

This section presents the performance and design requirements for the Environmental Control and Life Support Subsystems (EC/LSS) of the Two Compartment Laboratories, the Interim Station, and the Operational Station. Requirements for the EC/LSS of the One Compartment Dependent Laboratory are not stated because the components are primarily Apollo type. The major components of this EC/LSS are listed, however, to show sequential growth throughout the space station family.

The EC/LSS have the following functions:

- Atmospheric control. This includes control of temperature, pressure, humidity, and contaminants.
- Water management.
- Waste management.

The basic philosophy adopted for defining the EC/LSS of the Modular Multipurpose Space Station family was that a subsystem should be designed which would be suitable for all of the stations except the One-Compartment Dependent Laboratory. The subsystem of the Interim Station, sized for nine men, was designated as the standard to be used. It could be operated at less than capacity on the Two Compartment Laboratories, although a small weight penalty would be incurred. Also, four of these subsystems could be used, virtually unmodified, on the Operational Space Station.

The description and requirements following apply to all stations except the One Compartment Laboratory, bearing in mind that the Two Compartment Laboratories do not use all of the subsystem components. Table 4-4 will serve to identify the major features of the various stations.

#### 4.2.1.2 Performance Requirements

The Environmental Control and Life Support Subsystems shall meet the specifications given in Tables 4-4 and 4-5.

#### 4.2.1.3 Design Requirements

The Environmental Control and Life Support Subsystems shall meet the general requirements listed in Section 4.2.

The primary philosophy for the EC/LSS shall be in accordance with paragraph 3.5.1, i.e., a nominal nine-man subsystem designed for the Interim Modular Space Station shall be utilized for the other stations of the family. However, consideration shall be given to subsystem modularization as discussed in paragraph 3.5.1.5.

Table 4-4  
MAJOR FEATURES-EC/LSS

I T E M	S T A T I O N	One-Compt. Dependent Laboratory	Two-Compartment Laboratories			Interim Station	Operational Station
			Independent	Polar	Synchro- nous		
Atmosphere		O <sub>2</sub>	O <sub>2</sub> -N <sub>2</sub>	O <sub>2</sub> -N <sub>2</sub>	O <sub>2</sub> -N <sub>2</sub>	O <sub>2</sub> -N <sub>2</sub>	O <sub>2</sub> -N <sub>2</sub>
Compartment Pressure, PSIA		5	7	7	7	7	3.5-14.7
Oxygen Partial Pressure, PSIA		N.A.	3.5	3.5	3.5	3.5	3.5
Oxygen Regeneration		No	No	No	No	Yes	Yes
Atmospheric Storage, Primary		Supercrit. Cryogenic	Subcritical Cryogenic	Subcritical Cryogenic	Subcritical Cryogenic	Subcritical Cryogenic	Subcritical Cryogenic
Storage-Repress., Airlock, Backpack		Hi Pr. Gas	Hi Pr. Gas	Hi Pr. Gas	Hi Pr. Gas	Hi Pr. Gas	Subcritical Cryogenic
Relative Humidity, %		50 ± 10	50 ± 10	50 ± 10	50 ± 10	50 ± 10	50 ± 10
Compartment Temperature, Deg. F		75 ± 5	75 ± 5	75 ± 5	75 ± 5	75 ± 5	75 ± 5
CO <sub>2</sub> Limit Partial Pressure, MM. Hg		7.6	7.6	7.6	7.6	7.6	7.6
CO <sub>2</sub> Management		LiOH	Mol. Sieve	Mol. Sieve	Mol. Sieve	Mol. Sieve	Mol. Sieve
Contaminant Management		Act. Charcoal Chemis- orbent	Act. Charcoal Chemis- orbent Catal. Burner	Act. Charcoal Chemis- orbent Catal. Burner	Act. Charcoal Chemis- orbent Catal. Burner	Act. Charcoal Chemis- orbent Catal. Burner	Act. Charcoal Chemis- orbent Catal. Burner
Water Reclamation		No-Fuel Cell By-Product	Yes-Urine, Atmos., Wash Water	Yes-Urine, Atmos., Wash Water	Yes-Urine, Atmos., Wash Water	Yes-Urine, Atmos., Wash Water	Yes-Urine, Atmos., Wash Water
Waste Management		Apollo Dependent	Collection Process, & Storage	Collection, Process, & Storage	Collection, Process, & Storage	Collection, Process, & Storage	Collection, Process, & Storage With Water or O <sub>2</sub> Recovery

Table 4-5  
NOMINAL CREW REQUIREMENTS - EC/LSS

Oxygen Consumption, lb/man-day	1.8
Carbon Dioxide Output, lb/man-day	2.1
Metabolic Heat Rejection, Btu/man-day	
Nominal	11,200
Minimum	7,200
Maximum	17,250
Water Consumption, lb/man-day	
Drinking and Food	6.16
Wash	2.18*
Waste Production, lb/man-day	
Garbage	0.1
Feces	0.33
Urine	3.48
Refuse	0.4

\*All stations except Operational which has wash water allowance of 9.84 lb/man-day.

The atmospheric conditioning loops shall be arranged as indicated in Figure 4-9. Air flow through the compartments shall be sufficient to assure a comfortable environment for the crew. The compartment walls shall be kept free of condensation. This shall be accomplished, if necessary, by forced airflow along the walls.

The station atmospheres shall comply with the information given in Table 4-4. This shall include atmospheric constituents, pressure, humidity values, and temperature limits.

The Interim and Operational Stations shall be provided with oxygen regeneration equipment which shall be arranged as indicated in Fig. 4-10. The Bosch process for oxygen regeneration shall be utilized.



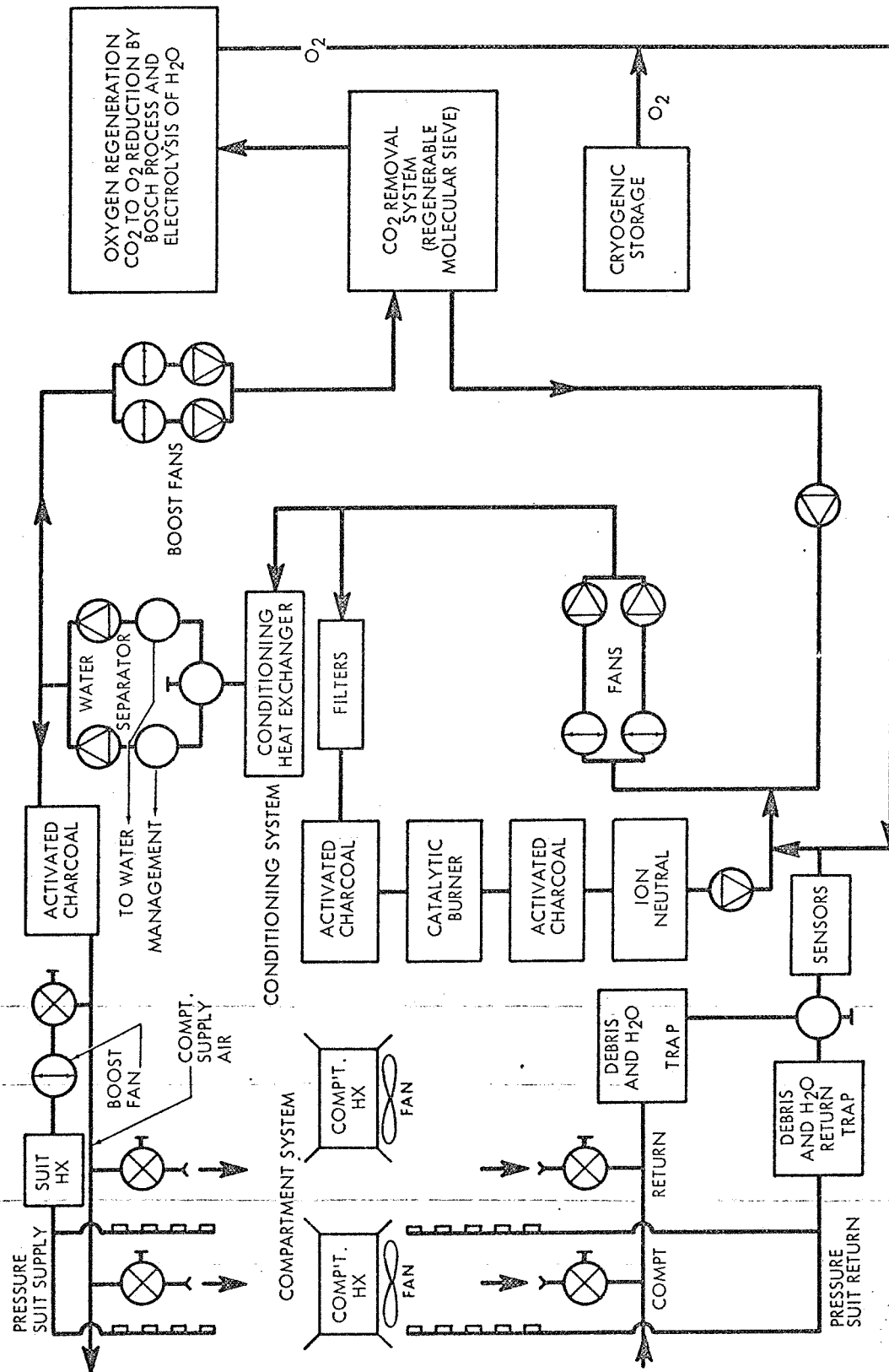


FIG. 4-9 THERMAL AND ATMOSPHERIC CONTROL FLOW DIAGRAM

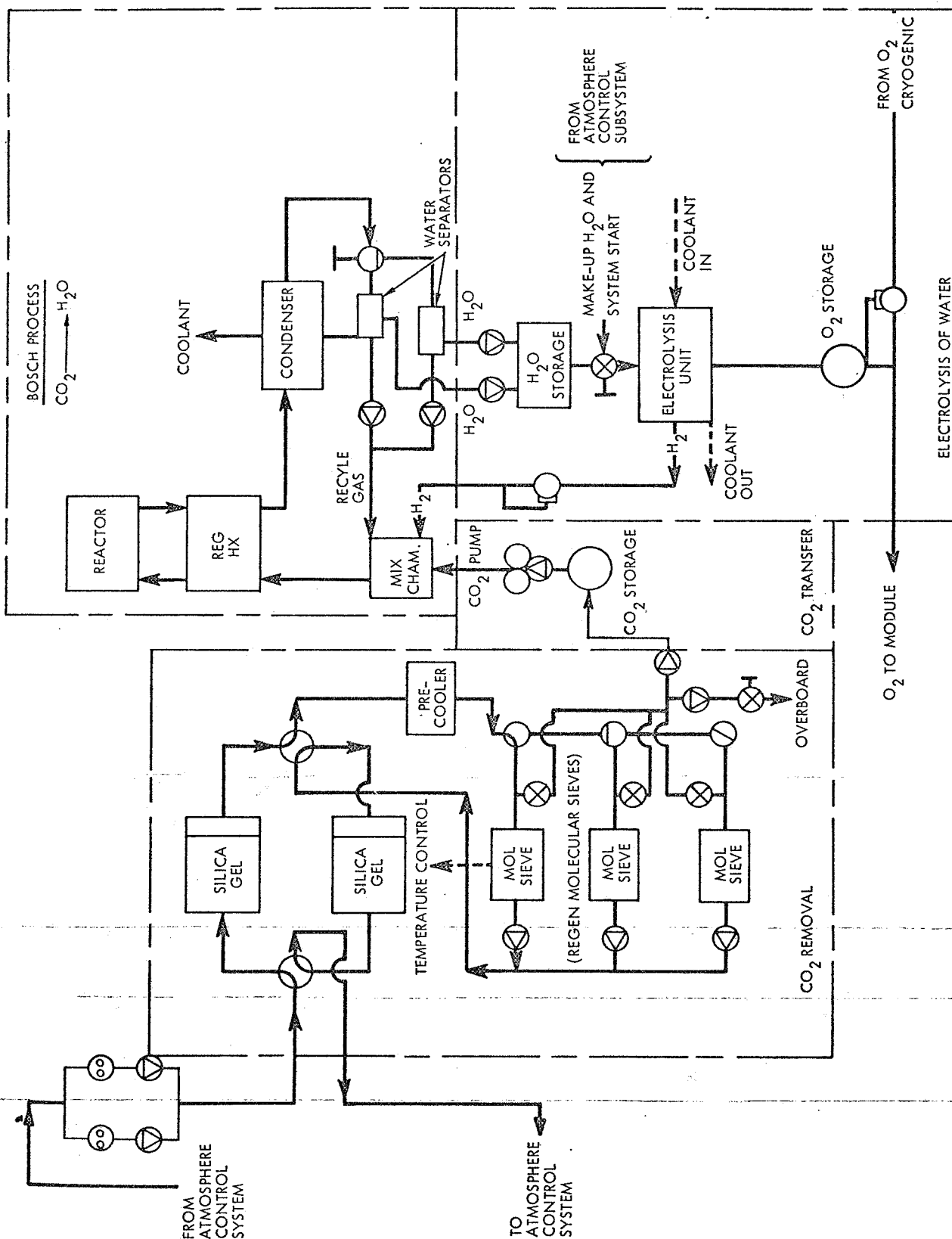


FIG. 4-10 OXYGEN REGENERATION SYSTEM

Atmosphere storage shall be subcritical cryogenic for the primary supply. The secondary supply, for repressurizations, airlocks, and backpacks, shall be subcritical cryogenic for the Operational Station and high pressure gas for the other stations. Storage and supply systems shall be arranged as shown in Figures 4-11 and 4-12.

Resupply of cryogenic liquids, where applicable, shall be by pipeline transfer. Resupply of high pressure gases shall be by tank transfer.

Carbon dioxide partial pressure shall be kept below a limit of 7.6 mm Hg. Carbon dioxide removal shall be accomplished through the use of molecular sieves. Silica gel beds shall be provided upstream of the molecular sieves to prevent their being "poisoned" with moisture in the atmosphere. The arrangement of molecular sieves and silica gel beds shall be as shown in Figure 4-10.

Contaminants other than  $\text{CO}_2$  shall be removed by filters, activated charcoal, catalytic burners, and ion neutralizers. Consideration shall be given to the equipment shown in Figure 4-13. The high efficiency filters shall be capable of removing 98 percent of material 0.07 micron in diameter and 100 percent of material 0.9 micron in diameter.

Temperature control of the electronic equipment necessary for station operation shall be accomplished by both air and liquid cooling. As a preliminary estimate, 30 percent of the selectronic heat load shall be removed by air and 70 percent by liquid cooling. Liquid cooling shall be accomplished by cold plates. Maximum cold plate temperature shall be 100 deg. F.

The compartment air shall be temperature controlled by individual compartment heat exchangers arranged in parallel as shown in Figure 4-9.

The primary liquid circulation loop shall be arranged, in general, as shown in Figure 4-14, bearing in mind that not all of the stations have as many compartments as shown. If an isotope heating system for  $\text{CO}_2$  desorption and waste treatment is incorporated in the station, it shall be integrated into the system through a secondary loop as

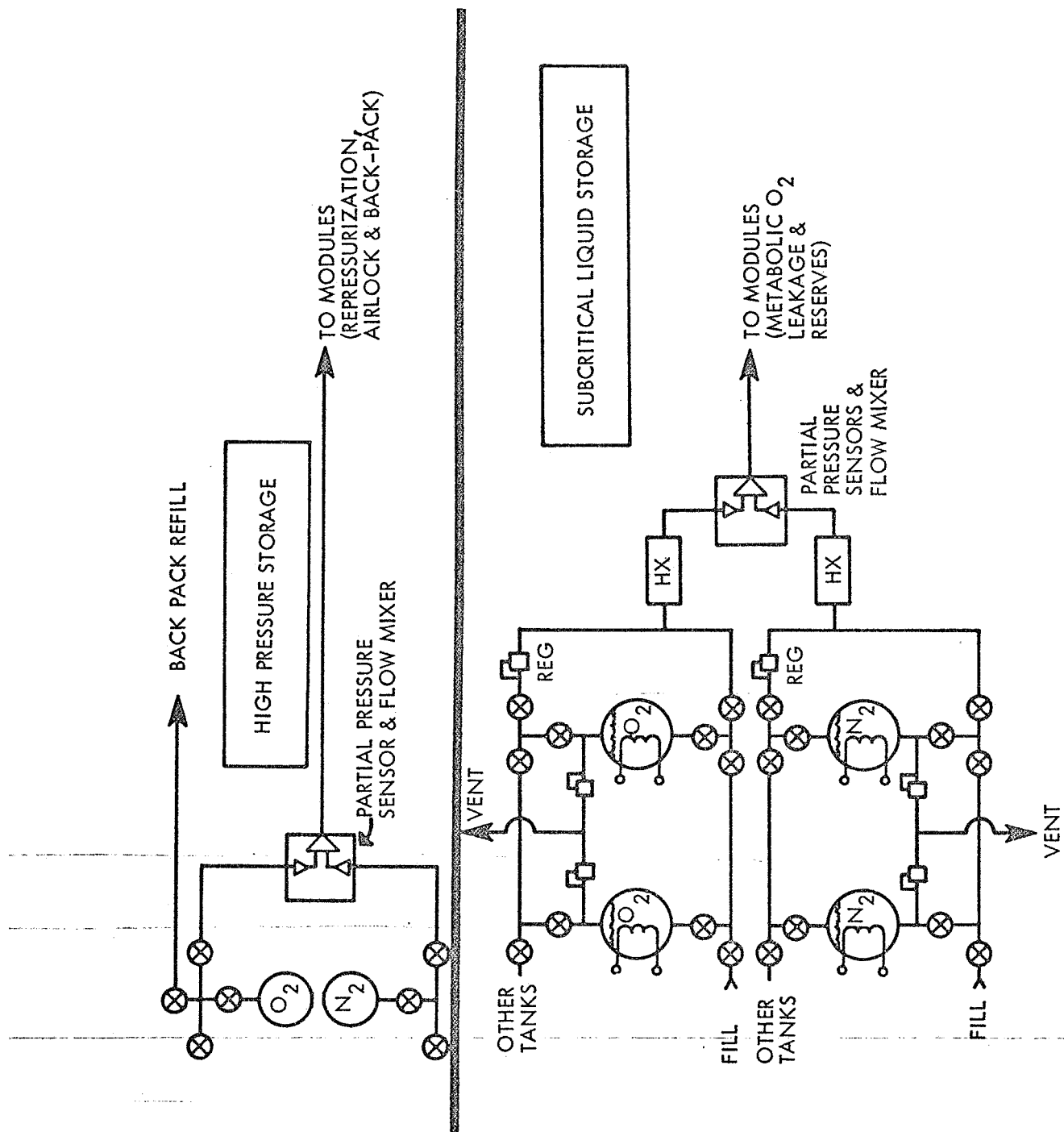


FIG. 4-11 ATMOSPHERE STORAGE SCHEMATIC

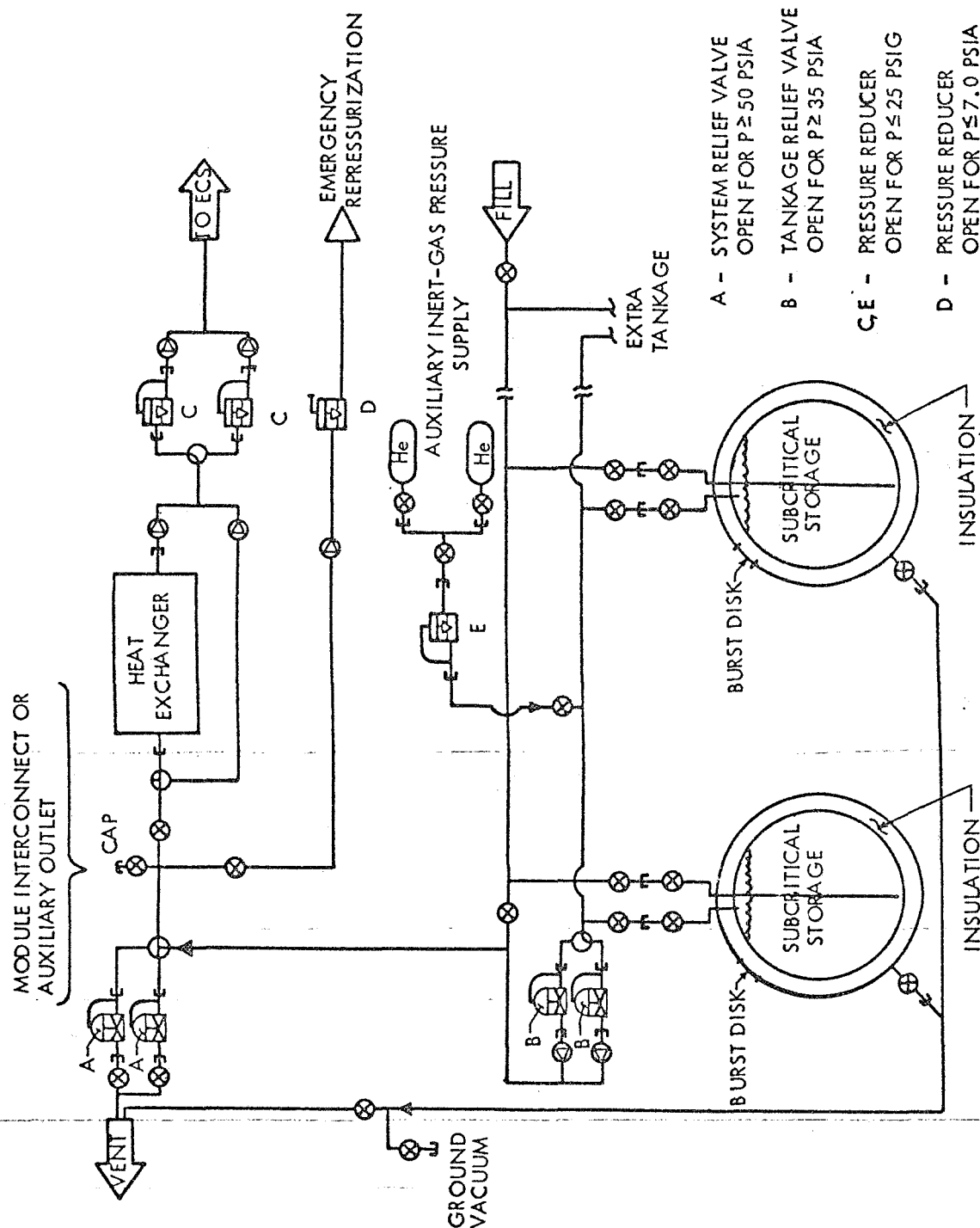
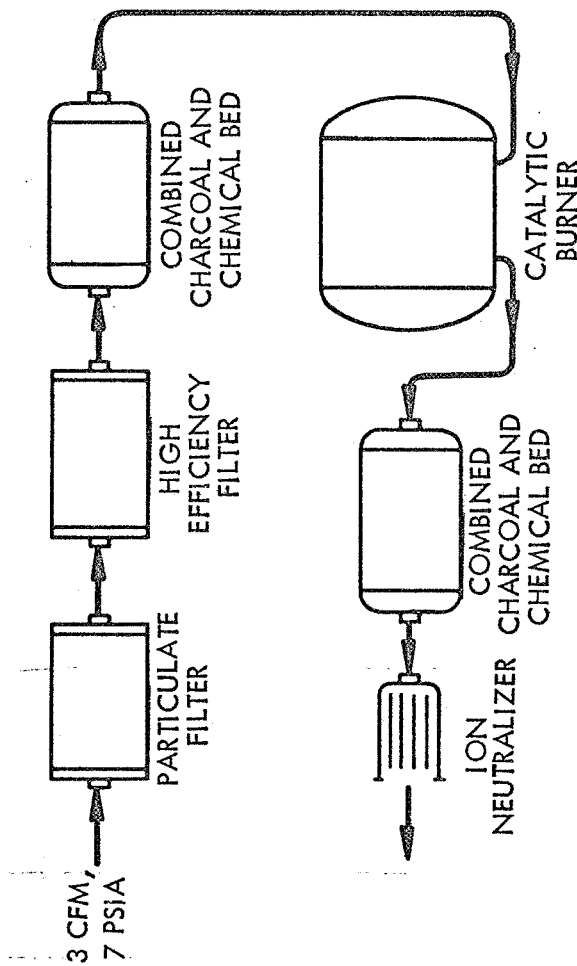


FIG. 4-12 SUBCRITICAL STORAGE AND SUPPLY FOR THE OPERATIONAL STATION



WEIGHT AND VOLUME ESTIMATES	WEIGHT (lb)	DIMENSIONS
PARTICULATE FILTER	1.5	3 1/2" DIAM x 14" LONG
HIGH-EFFICIENCY FILTER	1.5	3 1/2" DIAM x 14" LONG
COMBINED CHARCOAL AND CHEMICAL BED	2.0	3" DIAM x 12" LONG
CATALYTIC BURNER FOR 3 CFM FLOW	17.0	9" DIAM x 18" LONG
ION NEUTRALIZER	0.5	2" DIAM x 3" LONG
TOTAL	22.5	

NOTE:  
MRD DIVISION, GENERAL AMERICAN TRANSPORTATION CORPORATION

FIG. 4-13 CONTAMINANT REMOVAL EQUIPMENT

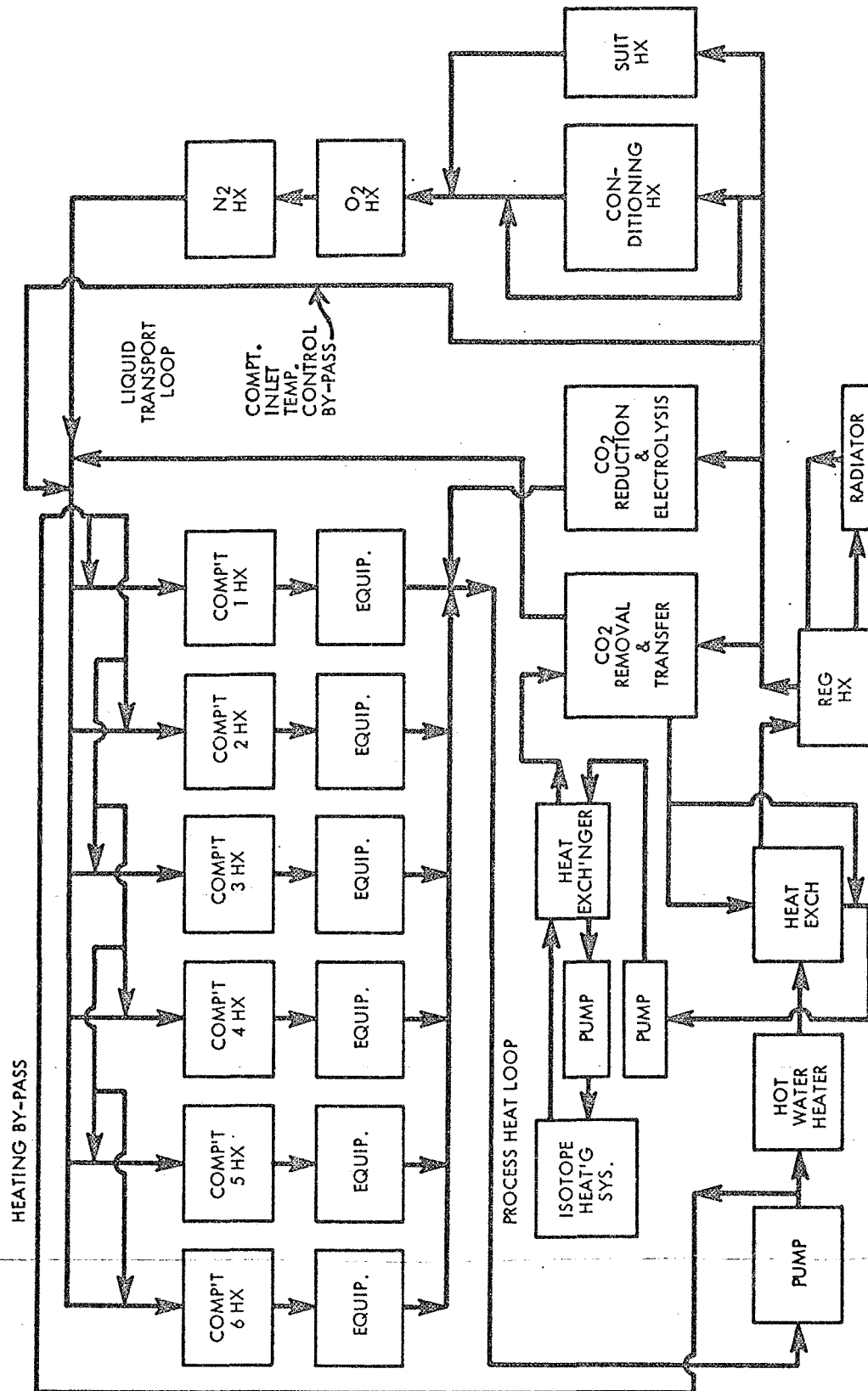


FIG. 4-14 LIQUID CIRCULATION SYSTEM, INTERIM STATION

indicated in Figure 4-14. The liquid coolants shall be FC-75 for the primary and XF-1050 for the secondary loop. Liquid cooled equipment shall be in series with the compartment heat exchangers.

Radiator outlet temperature shall be controlled to approximately 40 deg F. Consideration shall be given to modularizing the radiators, i.e., utilizing a number of identical radiator panels. Excess radiator area shall be provided so that design heat rejection may be maintained even though one or more panels fail. In the design of the radiators, consideration shall be given to the control technique of sequential freeze-up of designated panel sections by means of suitable orificing of coolant flow to the various sections. Radiators shall be mounted on the cylindrical surface of the modules and located, considering the orientation of the stations, such that both earth albedo and solar radiation effects will be minimized.

In calculating radiator area, it shall be assumed that the station surfaces will be coated with white silicone paint. For this paint, the assumed surface emissivity shall be 0.90 and the assumed solar absorbtivity shall be 0.40 after ultraviolet exposure.

Consideration shall be given to the use of an isotope heating source for CO<sub>2</sub> desorption and waste processing. Based on current knowledge of isotope availability, half life, and shield weight penalty, the primary choice shall be plutonium 238. Shielding requirements shall be based on the crew dosage limits specified in Section 3.2 of this report. Heat rejection equipment for the isotope heat source shall include emergency provisions adequate to dissipate all generated heat in the event that coolant flow through the isotope core is lost. A feasible method shall be developed for disposing of the isotope at the end of the station mission.

Water management subsystems shall be based on the requirements listed in Table 4-5. The logistic resupply of water shall be minimized through the use of reclamation devices which produce potable water from



urine, atmospheric condensate, and wash water. Reclamation of potable water from fecal matter shall not be a requirement. However, consideration shall be given to reclamation of water from this source for use as radiation shielding, oxygen make-up, or ballast on the Operational Station.

The water management subsystems shall be arranged, in general, as indicated in Figure 4-15. Dual accumulators shall be provided so that water potability may be tested. Water pressure shall be 35 psia, maintained by nitrogen gas. Water heaters and coolers shall be provided to satisfy the requirements listed in Table 4-6.

Table 4-6

## STATION WATER HEATING REQUIREMENTS

<u>Item</u>	<u>Temp., Deg F</u>
Drinking	75
Personal Washing	75 - 100
Washing Machine	75 - 120
Galley	75 - 160

Atmospheric condensate shall be reclaimed by means of the equipment shown in Figure 4-16. Electrodialysis with membrane permeation as shown in Figure 4-17, shall be utilized to reclaim potable water from urine and wash water.

The waste management equipment shall be capable of handling wastes in the quantities listed in Table 4-7.

Table 4-7

## WASTE MANAGEMENT

<u>Type of Waste</u>	<u>Quantity (lb/man-day)</u>
Garbage (2/3 H <sub>2</sub> O)	0.1
Feces (2/3 H <sub>2</sub> O)	0.33
Urine	3.48
Refuse	0.4
TOTAL	4.31

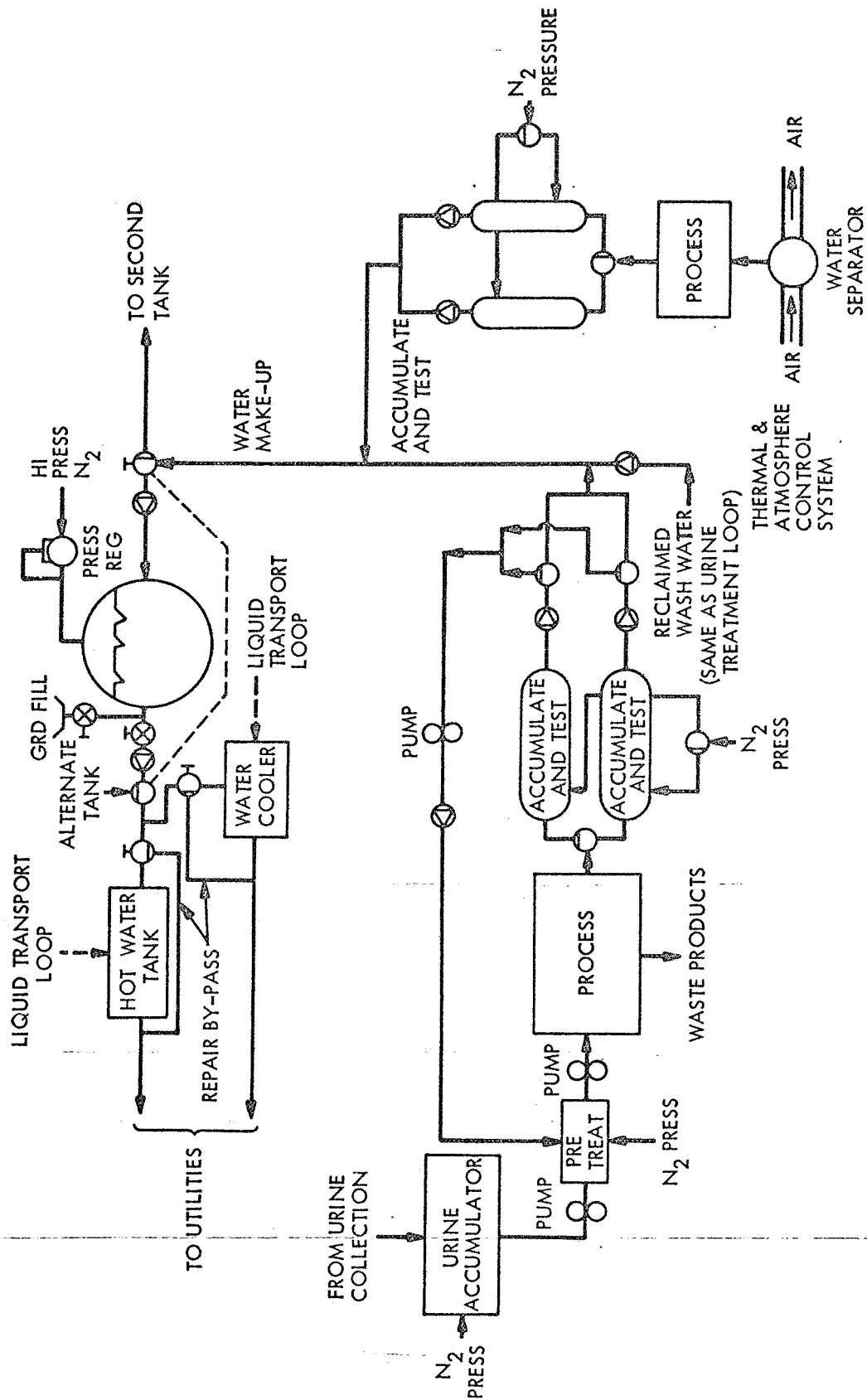


FIG. 4-15 WATER MANAGEMENT SYSTEM

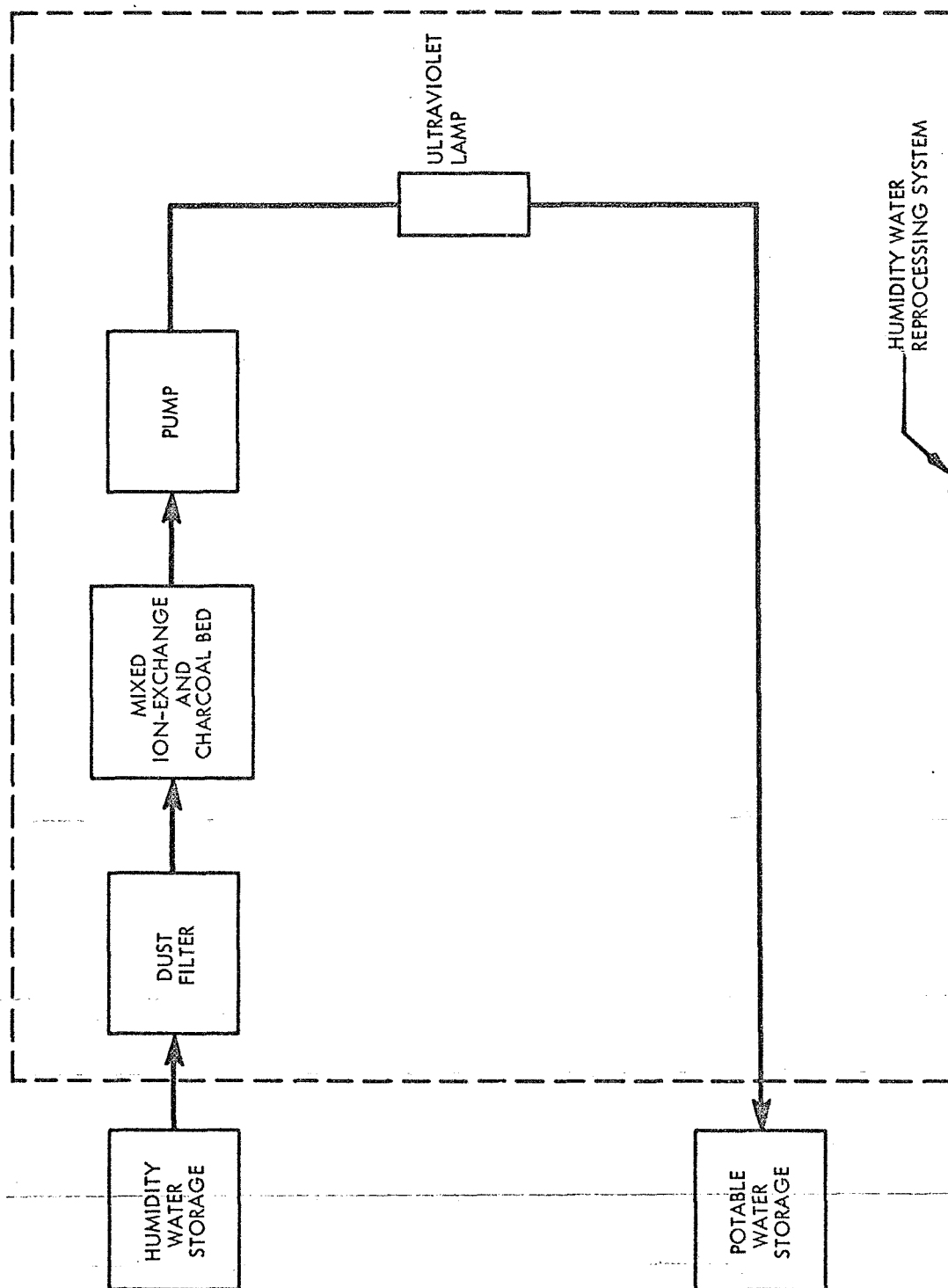


FIG. 4-16 HUMIDITY WATER RECLAMATION SCHEMATIC

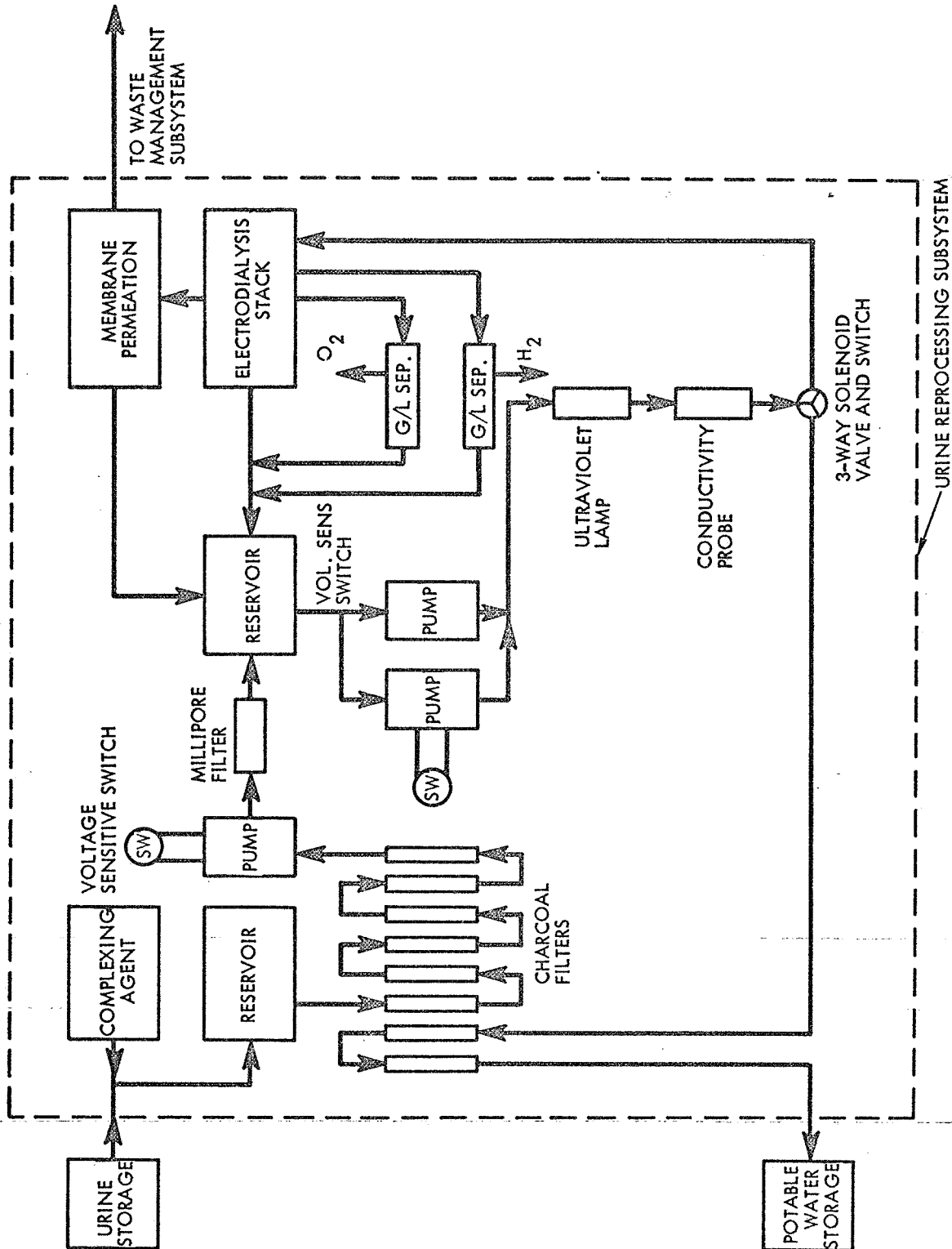


FIG. 4-17 ELECTROLYSIS WATER RECLAMATION SCHEMATIC

The equipment and arrangement shown in Fig. 4-18 shall be considered the preliminary choice for a solid waste management subsystem. All wastes shown in Table 4-7 except urine are manually transferred to the drying units and are later stored in a common container.

#### 4.2.2 Electric Power

Design features and requirements of Electric Power Subsystems are presented in this section. The One Compartment Laboratory, the Two Compartment Laboratories, the Interim Station and the Operational Station are discussed. The Apollo Extensions are omitted because their types of electric power subsystems will not be changed.

The Electric Power Subsystems for the Modular Multipurpose Space Station family are based on two basic modular power sources.

- A two-kw fuel cell module. Two hydrogen-oxygen fuel cells of one kw each supply the energy.
- A five-kw solar array module. The solar panel area for this module is normally 1360 sq ft but in the case of the Synchronous Orbit Laboratory, it is 680 sq ft.

The Electric Power Subsystems consist of the basic power sources, power storage units, conditioning units, distribution components, switching devices, and tanks and plumbing for fuel cell reactants, when applicable.

##### 4.2.2.1 Description

One-Compartment Dependent Laboratory. The original Apollo Electric Power Subsystem is supplemented by the addition of a single one-kw fuel cell (one half of a two-kw fuel cell module). Tanks are added to hold the additional fuel cell reactants. The subsystem is arranged as shown in Figure 4-19.

Two Compartment Laboratories (Independent and Polar). These stations each use a single five-kw solar array module as the primary power source. The solar array area is 680 sq ft for each power module. The arrangement of the subsystem is shown in Figure 4-19.

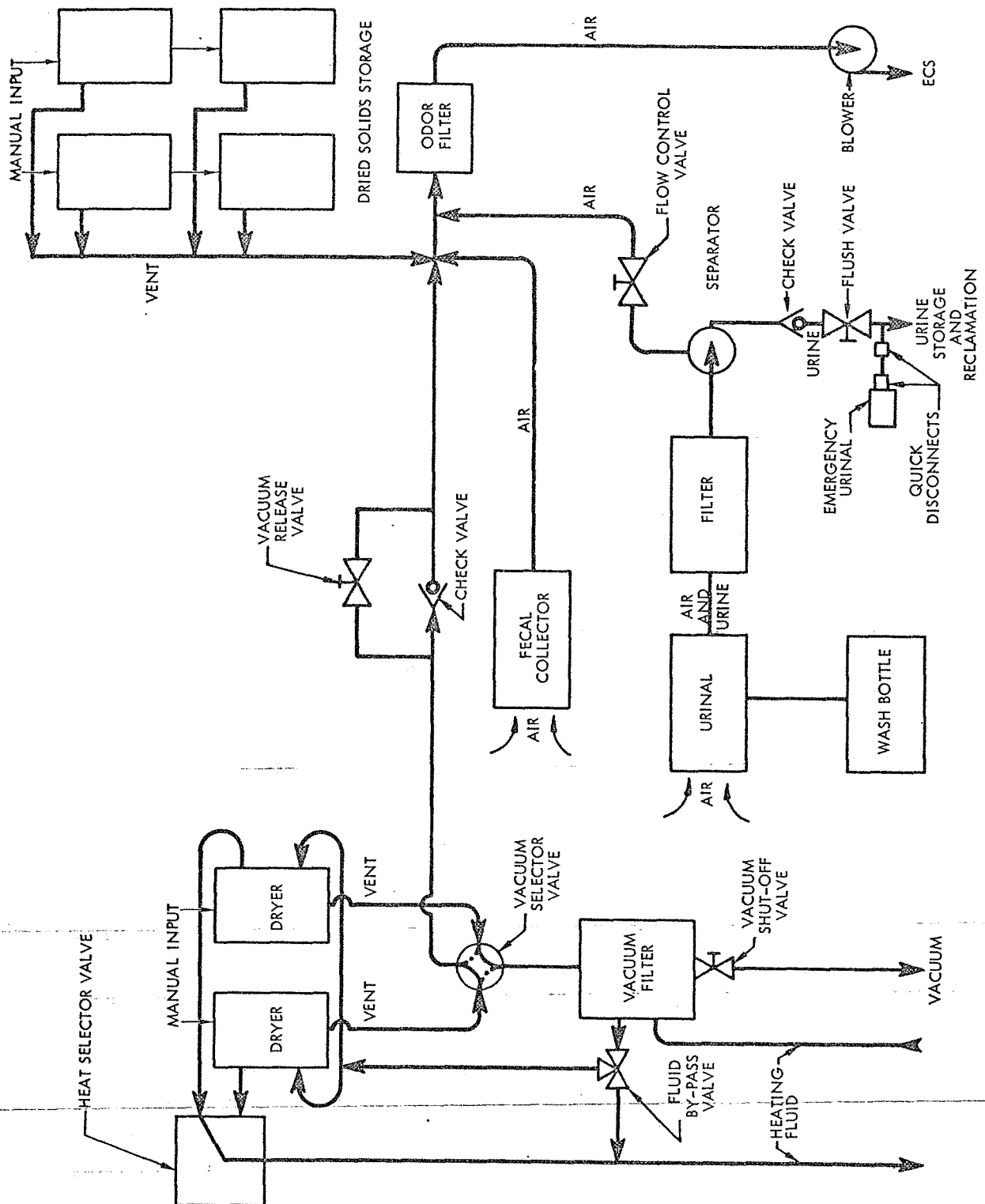
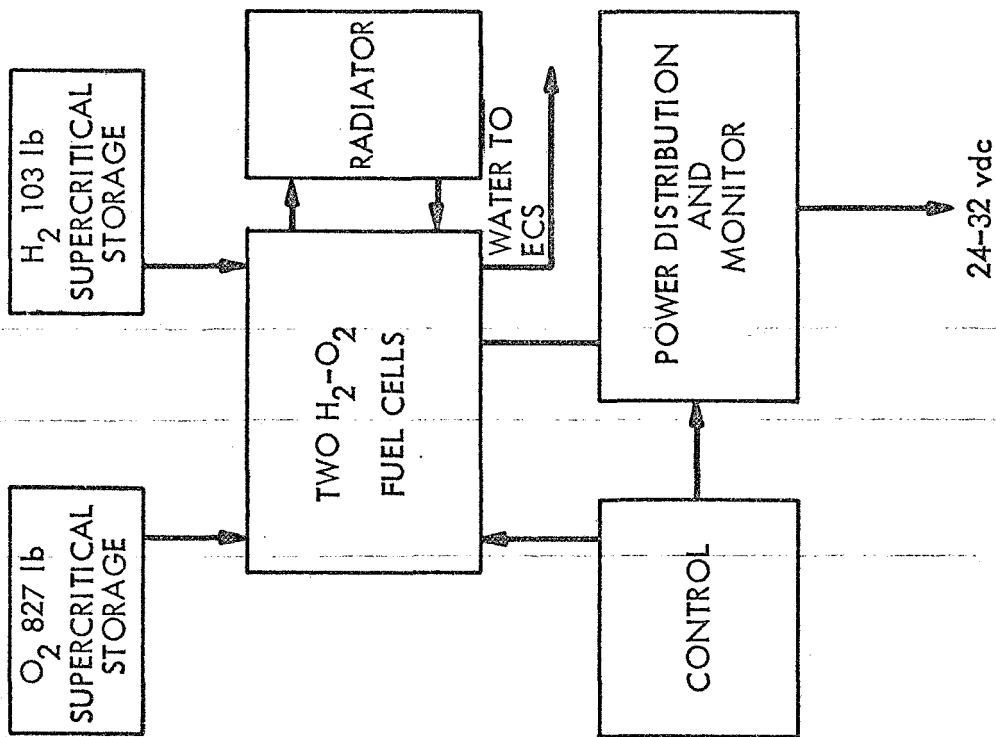


FIG. 4-18 WASTE MANAGEMENT SYSTEM SCHEMATIC

2 kw (1000 kw hr) FUEL CELL MODULE



5 kw SOLAR PHOTOVOLTAIC ARRAY

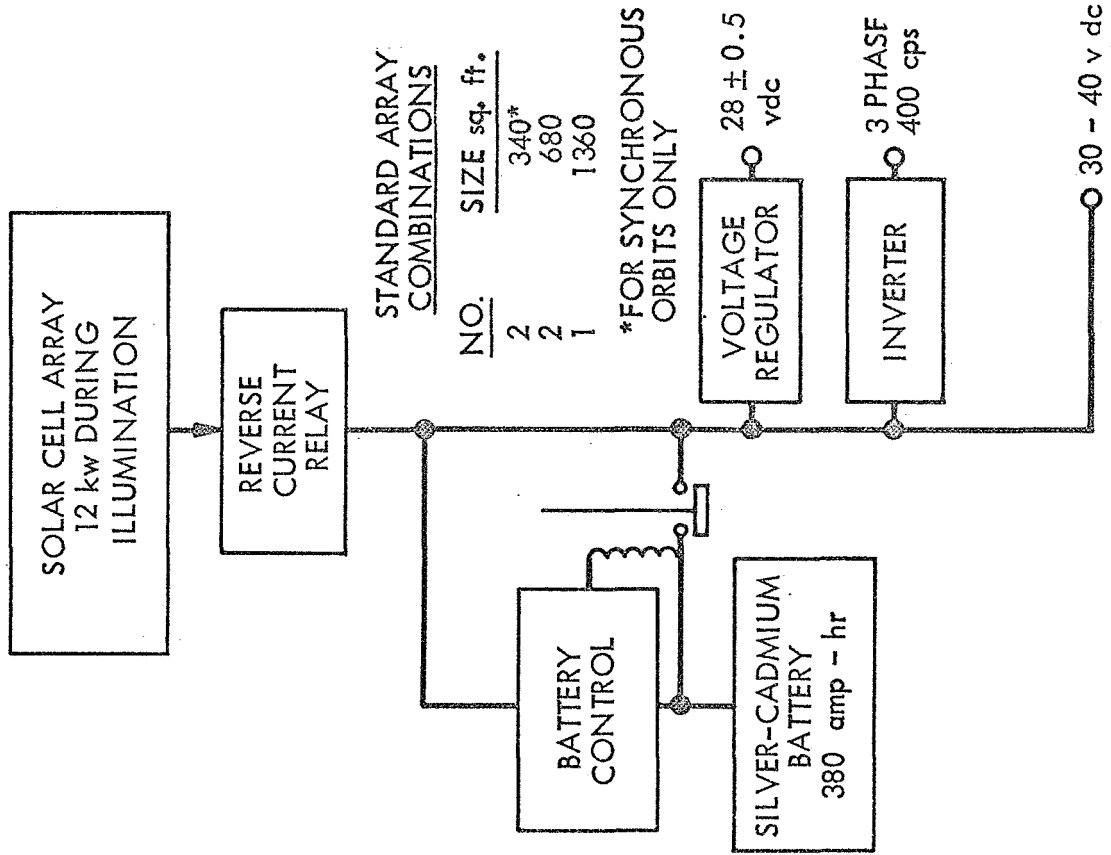


FIG. 4-19 ELECTRIC POWER SUBSYSTEM BUILDING BLOCKS

Two-Compartment Synchronous Laboratory. The Electric Power Subsystem for this station is similar to the other Two Compartment Laboratories except that the solar array area is 340 sq ft. This reduction in area is possible because battery recharging requirements are less as a result of the special orbit. A schematic of the system is shown in Figure 4-19.

Interim Modular Space Station. Two of the five-kw solar array modules are used to provide electric power for this station. Total solar array area is 1360 sq ft. A two-kw fuel cell module provides back-up power. The subsystem is arranged in a manner similar to that of the Operational Space Station (see Figure 4-20).

Operational Modular Space Station. Six of the five-kw solar array modules provide primary electric power for this station. Pre-deployment and back-up power are supplied by a two-kw fuel cell module. Total solar array area is 8160 sq ft. A schematic of the subsystem is shown in Figure 4-20.

#### 4.2.2.2 Performance Requirements

The Electric Power Subsystems shall meet the requirements listed in Table 4-8.

#### 4.2.2.3 Design Requirements

Components of the Electric Power Subsystems shall meet the general design requirements stated in Section 4.2.

All Electric Power Subsystems utilizing solar arrays for their primary power sources shall be designed so that the solar arrays and batteries may be replaced during the manufacturing phase with advanced dc energy sources when such systems become available if the use of the advanced equipment can be shown to be advantageous. Consideration shall also be given to in-orbit replacement of the solar arrays and batteries with advanced dc power sources.



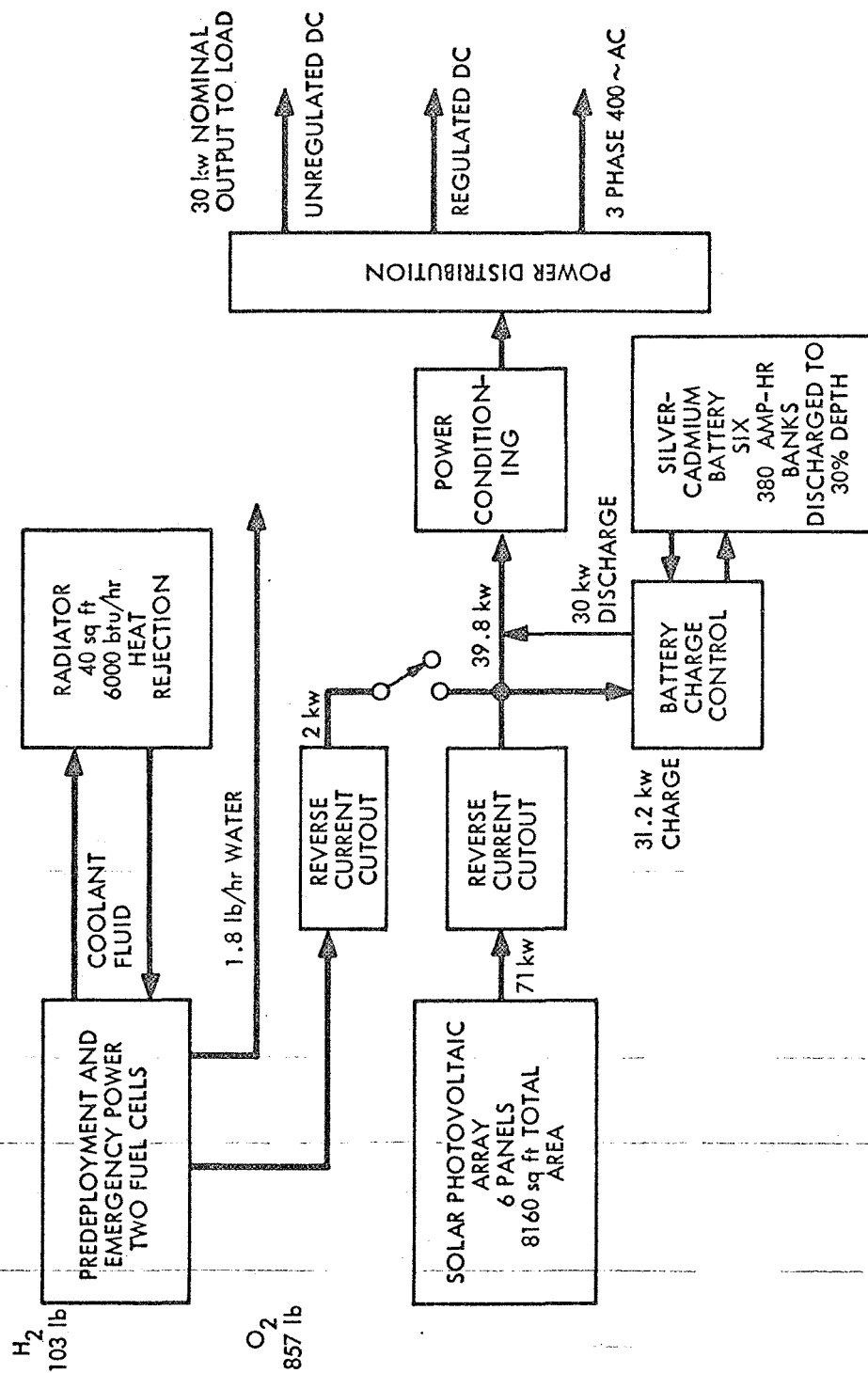


FIG. 4-20 ELECTRIC POWER SUBSYSTEM - OPERATIONAL SPACE STATION

Table 4-8  
ELECTRIC POWER SUBSYSTEM REQUIREMENTS

Type of System	One Compt. Dependent Laboratory	Two Compartment Laboratories			Interim Station	Operational Station
		Independent	Polar	Synchronous		
Fuel cells + Batteries	Fuel cells + Batteries	Solar Array + Batteries			Solar Array + Batteries, Fuel cell + Battery backup	
Power Requirement, kw	1.5	5	5	5	10	30
No. of 2 kw fuel cell/ Battery Modules	1½ $\Delta$	--	--	--	1	1
No. of 5 kw solar array/ Battery Modules	---	1	1	1	2	6
Orbital Energy Develop- ed, KWHR	1,620	4.28x10 <sup>4</sup>	1.08x10 <sup>4</sup>	1.08x10 <sup>4</sup>	0.4x10 <sup>6</sup> $\Delta$	1.3x10 <sup>6</sup> $\Delta$
Battery Storage Capa- bility, KWHR		4.5	4.5	1	9	27
Solar Array Module Unregulated DC output	N.A.	36-41 volts				
Solar Array Module Regulated DC output	N.A.	28 ± 0.5 volts				
Solar Array Module A C output	N.A.	115/200 volts, 3 phase, 400 cps				
Total Solar Array Area, Sq. Ft.	N.A.	1360	1360	680	2720	8160
Fuel Cell Module Radiator Area, Sq.Ft.	40	N.A.	N.A.	N.A.	40	40

Notes:  $\Delta$  1 One complete fuel cell module plus one extra fuel cell

$\Delta$  2 For a five-year mission

Solar array design shall be based on an initial output of 11.1 watts per sq ft, degrading to 8.8 watts per sq ft over a 5 to 10-year period.

Solar array power modules shall be built in five-kw subdivisions and these modules or multiples of them shall be used to provide primary electric power on all stations except the One Compartment Dependent Laboratory. The number of five-kw solar array power modules for the various stations shall be as shown in Table 4-8. Each five-kw solar array power module shall have its own rechargeable batteries, power conditioning components, switching and control devices, and monitoring equipment.

The electric power subsystem for the Operational Station shall be controllable from both the primary and secondary control centers.

Fuel cell power modules shall be designed to produce two kw and these power units shall be utilized on the One Compartment Dependent Laboratory, the Interim Station, and the Operational Station. The Dependent Laboratory shall contain one complete fuel cell module (two fuel cells) plus one extra fuel cell. The Interim and the Operational Stations each utilize one fuel cell module. The fuel cell power modules shall each contain two fuel cells and the modules shall contain power conditioning, switching, monitoring, and control equipment.

Fuel cell power modules shall have radiators independent of those used for the Environmental Control subsystem. The radiator area shall be 40 sq ft for each of the three applicable stations.

The battery power conditioning components, distribution equipment, and control devices shall be capable of handling short-term peak power overloads of 50 percent without damage to the equipment. Current-limiting devices, adequate wiring, and delayed action circuit breakers shall be employed so that transient overloads of 100 percent may be handled for one to two seconds. Station subsystems shall be protected against damage by overvoltage, undervoltage, overfrequency, and underfrequency devices.

Target weights for the various electric power subsystems shall be as shown in Table 4-9.

Table 4-9  
ELECTRIC POWER SUBSYSTEM CHARACTERISTICS

Type of Station	Power Rating (kw)	Fuel Cell Module			5 kw Solar Array Modules			Total System Weight (lb)
		Dry Weight	Reactant Weight	No. of Fuel Cells	No. Req. Arrays	Array (sq ft)	Weight (lb)	
1 Compt. Depend.	1.5	2222	1860	3	0	0	0	4,082
2 Compt. Independ.	5.0	0	0	0	1	680 Ea.	3,200	3,200
2 Compt. Polar	5.0	0	0	0	1	680 Ea.	3,200	3,200
2 Compt. Synchr.	5.0	0	0	0	1	340 Ea.	1,800	1,800
Interim Station	10.0	1614	930	2	2	1360 Ea.	6,400	8,944
24 Man Oper. Sta.	30.0	1614	930	2	6	1360 Ea.	19,200	21,744
36 Man Oper. Sta.	30.0	1614	930	2	6	1360 Ea.	19,200	21,744
All Subsystems								
Nominal System Voltage - 24-30 vdc								
Overload Capability - 100% Peak Transient 50% Sustained								

#### 4.2.3 Communication, Command, and Tracking

This section presents requirements for the Communication, Command, and Tracking Subsystem of the One Compartment Dependent Laboratory, the Two Compartment Laboratories, and the Interim and Operational Space Stations.

This subsystem performs the following functions:

- Transmits vocal, digital, and pictorial data to the ground at any of several frequencies.
- Accepts vocal, digital, and pictorial information from the ground.
- Cooperates with ground based tracking radar.
- Communicates with logistics spacecraft and cooperates with rendezvous radar when such functions are applicable.
- Accomplishes intercommunication within the stations.

The subsystem accomplishes the functions listed above through the use of radio receivers and transmitters, television receivers and cameras, and associated components such as amplifiers, diplexers, multiplexers, antennas, switches, etc. A representative list of components is typified by Table 4-10.

##### 4.2.3.1 Description

The Communication, Command, and Tracking Subsystems for the various stations are described in Section 3.5.3 and their evolution is shown in Table 4-11.

The One Compartment Dependent Laboratory retains the Apollo equipment in the Command Module and supplements it with a voice control unit and a remote control panel in the laboratory.

The Two Compartment Independent, Polar, and Synchronous Laboratories will retain the Apollo equipment in the Command Module and supplement it with similar equipment in the laboratory modules. In addition, the Independent Laboratory will incorporate a rendezvous radar. The equipment complement for these stations is shown in Table 4-12.

Table 4-10  
EQUIPMENT COMPLEMENT OF THE COMMUNICATIONS, COMMAND, & TRACKING SUBSYSTEMS  
FOR THE TWO-COMPARTMENT LABORATORIES

ITEM	DIMENSIONS (In.)			WEIGHT (lb )	POWER (Watts)
	H	W	L		
HF Transceiver	6.0	4.0	7.0	5.0	45.0
VHF/AM Rec.-Trans.	6.0	4.7	10.0	11.0	54.5
400-Mc Command Receiver	-	-	-	3.6	0.5
S-band Transponder (dual)	6.0	9.5	21.0	31.0	16.0
S-band Power Amplifier	6.0	5.75	22.3	30.0	35/85
Pre-modulation Processor	6.0	4.7	10.6	14.5	11.0
PCM Telemetry, high level*	7.7	13.8	14.4	-	8.7
PCM Telemetry, low level*	4.5	10.5	6.0	-	4.2
Signal Conditioning Equipment*	6.0	9.8	23.0	-	90.0
Data Storage Equipment*	6.0	9.5	22.0	-	38.0
Audio Center	5.75	4.7	6.4	5.25	12.8
C-band Transponder	(4.4)	(9.4)	(13.0)	(23.8)**	(75.0)
Total for two units	8.8	9.4	13.0	47.6	75.0
Rendezvous Transponder, Up Data Link, Rendezvous Ranging	4.4	9.4	22.0	34.0	29.0
Triplexer	4.5	10.5	6.0	14.0	-
Command Module Remote Control				10.0	25.0
Box Total				206.0	
+ Antennas, cables, etc.		1050 cu in.		170.0	
				376.0	
*Accounted for in Data Management					
**Two required, see next line.					

Table 4-11  
CONFIGURATION EVOLUTION - COMMUNICATION, COMMAND, AND TRACKING SUBSYSTEMS

	One Compartment Dependent Laboratory	Two Compartment Laboratories			Interim Station	Operational Station
		Independent	Polar	Synchronous		
System Type	Apollo	Apollo	Apollo	Apollo	Advanced	Advanced
Autonomy	Apollo Dependent	Independent	Independent	Independent	Independent	Independent
Degree of Modification to Apollo System	Remote control, switching of data inputs or multiplexers, additional tape recorder	Minor	Minor	Reduce data rate, add high gain antenna	New System (higher data rates, an- tenna phase control provisions*)	New System with antenna phase con- trol**
Number of ground stations used	All GOSS	Partial GOSS	All GOSS	1 Station	2 Stations	2 Stations
Maximum data rates	51.2k BPS	51.2k BPS	51.2k BPS	12.8k BPS	192k BPS	384k BPS
					*Transponders will have phase control provisions included; not needed for operational system, but experiment using two antennas should be conducted.	**Phase control required





## EQUIPMENT COMPLEMENT FOR THE

Item	Description	Volume Each (Cu.In.)	Weight Each (Lb.)	Power (%)
				Rec. Only
1	S-Band Phase Controller & Modulator	170	12	-
2	S-Band Transponder & Power Amp.	400	24	10
3	UHF (400 Mc) Receiver-Transmitter	100	7	6
4	VHF (296.8 Mc) Receiver-Transmitter	85	6	5
5	UHF (450 Mc) Command Receiver (Dual)	90	7	3
6	Command Decoder (for both S-Band & 450 Mc)	360	11	10
7	HF Receiver-Transmitter	100	5	4
8	HF Power Amplifier	1000	22	-
9	VHF (137/243 Mc) ACQ. AID/EMERG. Receiver-Transmitter	100	5	0/5
10	C-Band Beacon Phase Controller	140	8	-
11	C-Band Beacon Transponder & Pwr Amp.	240	14	-
12	Intercom System - Master Station	600	30	-
13	Intercom System - Remote Station	60	3	-
14	Intercom System - Alarm - Call	120	7	-
15	Internal Radiation System (Interim)	275	17	-
16	Internal Radiation System (Oper)	1000	60	-
17	TV System - Cameras	70	4	-
18	TV System - Monitor, Small	1540	25	30
19	TV System - Monitor, Large	2500	40	42
20	TV Control, Scan & Sweep Gen.	2800	100	120
21	Communication Control Panel	2160	20	-
22	S-Band Diplexer	60	4	-
23	VHF/UHF Multiplexer	200	10	-
24	VHF/UHF Power Divider	70	4	-
25	VHF/UHF Docking Multiplexers	160	8	-
26	Coax Switch	20	2	-
27	HF Diplexer	100	6	-
28	HF Lobing Switch	100	8	-
29	Tri-Band Antenna & Deploy Mech.	300	14	-
30	VHF/UHF Docking Antenna	N.A.	2	-
31	Pre-Deployment Antenna	N.A.	2	-
32	Antenna Control Panel	430	5	-
33	C-Band Beacon Antenna	14	4	-
34	C-Band Beacon Power Divider	24	2	-
35	Rendezvous Transponder Antenna	24	7	-
36	Rendezvous Power Divider	40	4	-
37	Interconnect Cabling (Interim)	1350	215	-
38	Interconnect Cabling (Operational)	4800	600	-
39	Loose Equipment (Interim)	380	50	-
40	Loose Equipment (Operational)	1500	180	-

Table 4-12

FOR THE COMMUNICATION, COMMAND, AND TRACKING SUBSYSTEMS ON THE INTERIM AND OPERATIONAL MODULAR SPACE STATIONS

Weight (lb.)	Power (Each) (Watts)		INTERIM MODULAR SPACE STATION						OPERATIONAL MODULAR SPACE STATION					
			Oper. Quant.	Redund. Quant.	Volume Total (Cu.In.)	Weight Total (lb.)	Total Power (Watts)		Oper. Quant.	Redund. Quant.	Volume Total (Cu.In.)	Weight Total (lb.)	Total Power (Watts)	
	Rec. Only	Oper.					Rec. Only	Oper.					Rec. Only	Oper.
12	-	15	1	1	340	24	-	15	1	1	340	24	-	15
24	10	20	2	1	1200	72	20	40	3	1	1600	96	30	60
7	6	50	1	1	200	14	6	50	2	1	300	21	12	100
6	5	40	1	1	170	12	5	40	2	1	255	18	10	80
7	3	3	1	1	180	14	3	3	1	1	180	14	3	3
11	10	10	1	1	720	22	10	10	1	1	720	22	10	10
5	4	50	1	-	100	5	4	50	1	-	100	5	4	50
22	-	680	1	-	1000	22	-	680	1	-	1000	22	-	680
5	0/5	15/40	1	1	200	10	0/5	15/40	1	1	200	10	0/5	15/40
8	-	12	1	1	280	16	-	12	1	1	280	16	-	12
14	-	24	2	1	720	42	-	48	3	1	960	56	-	72
30	-	50	1	1	1200	60	-	50	1	1	1200	60	-	50
3	-	-	9	1	600	30	-	-	36	4	2400	120	-	-
7	-	6	2	1	360	21	-	12	7	1	960	56	-	42
17	-	3	1	-	275	17	-	3	-	-	-	-	-	-
60	-	10	-	-	-	-	-	-	1	-	1000	60	-	10
4	-	5	3	-	210	12	-	15	8	-	560	32	-	40
25	30	30	2	-	3080	50	60	60	6	-	9240	150	180	180
40	42	42	1	-	2500	40	42	42	2	-	5000	80	84	84
200	120	120	1	1	5600	200	120	120	1	1	5600	200	120	120
20	-	-	1	-	2160	20	-	-	2	-	4320	40	-	-
4	-	-	2	-	120	8	-	-	3	-	180	12	-	-
10	-	-	1	-	200	10	-	-	1	-	200	10	-	-
4	-	-	-	-	-	-	-	-	1	-	70	4	-	-
8	-	-	1	-	160	8	-	-	1	-	160	8	-	-
2	-	2	5	-	100	10	-	10	5	-	100	10	-	10
6	-	-	1	-	100	6	-	-	1	-	100	6	-	-
6	-	6	-	-	-	-	-	-	1	-	100	8	-	6
14	-	-	2	-	600	28	-	-	3	-	900	42	-	-
2	-	-	1	-	N.A.	2	-	-	1	-	N.A.	2	-	-
2	-	-	1	-	N.A.	2	-	-	1	-	N.A.	2	-	-
5	-	-	1	-	430	5	-	-	1	-	430	5	-	-
4	-	-	4	-	56	16	-	-	6	-	84	24	-	-
2	-	-	2	-	48	4	-	-	3	-	72	6	-	-
7	-	-	2	-	48	14	-	-	5	-	120	35	-	-
4	-	-	1	-	40	4	-	-	2	-	80	8	-	-
215	-	-	1 Set	-	1350	215	-	-	-	-	-	-	-	-
400	-	-	-	-	-	-	-	-	1 Set	-	4800	600	-	-
50	-	-	1 Set	-	380	50	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	1 Set	-	1500	180	-	-
					24,727	1,085						45,111	2,064	
					14.3							26.1		
					cu.ft.							cu.ft.		



The Communication, Command, and Tracking systems for the Interim and Operational Space Stations are advanced systems, essentially identical except that a smaller quantity of some items are required for the Interim Station. Components for these stations are listed in Table 4-12. A functional diagram of the Communication, Command, and Tracking subsystem for the Operational Station is shown in Figure 4-21.

#### 4.2.3.2 Performance Requirements

Performance requirements except for data rates, for the Communication, Command, and Tracking subsystems of the One and Two Compartment Laboratories shall conform to requirements stated by the manufacturer of the Apollo spacecraft. The Communication, Command, and Tracking subsystems of the Interim Station and the Operational Station shall meet the requirements given in Table 4-13 except for data rates. Data rates for all six stations shall be as specified in Table 4-11.

#### 4.2.3.3 Design Requirements

Communication, Command, and Tracking subsystem components shall conform to the general requirements stated in Section 4.2.

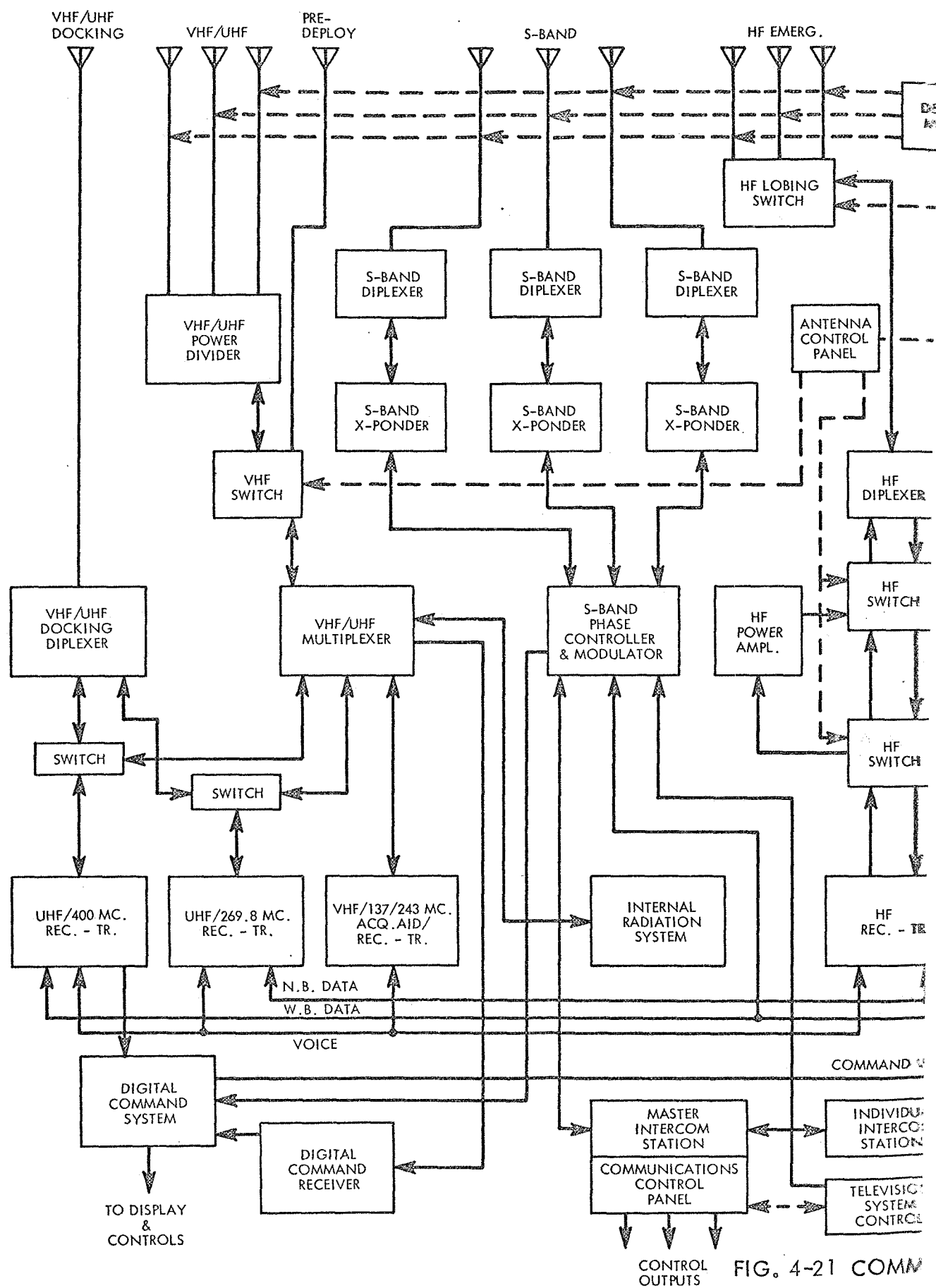
Components for the Interim Station and Operational Station subsystems shall be arranged in accordance with Figure 4-21.

Target weights for components in the Two Compartment Laboratories shall be as shown in Table 4-10 and for components in the Interim Station and Operational Station as shown in Table 4-12.

All the Communication, Command, and Tracking systems shall be designed to be compatible with the GOSS network.

The Two Compartment Synchronous Laboratory shall utilize medium gain antennas. All other stations may use low gain antennas.





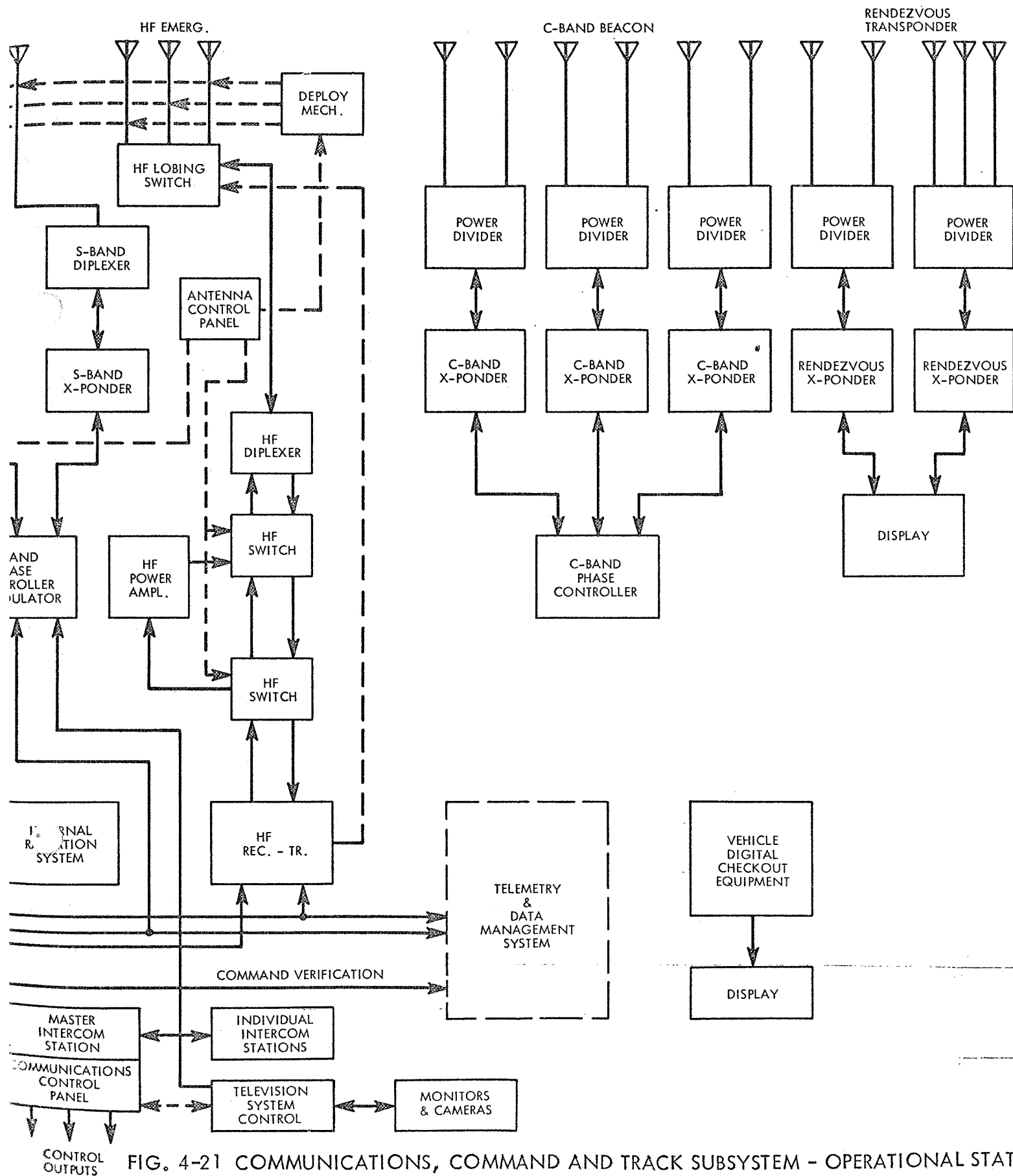


FIG. 4-21 COMMUNICATIONS, COMMAND AND TRACK SUBSYSTEM - OPERATIONAL STATION





Table 4-13  
COMMUNICATIONS AND TRACKING EQUIPMENT OPERATIONAL REQUIREMENTS

UHF/S-Band Space-To-Ground Voice and Data Link

Frequency:

Down	2290 Mc
Up	2110 Mc

Modulation:

Voice	FM/PM
Data	PCM/PM/PM

RF Bandwidth 6.8 Mc

Detection Bandwidths and Maximum Modulation Loss

PRN	100 cps	7 db
Voice	40 kc	7 db
Data (Lower Carrier)	192 kc	4 db
Data (Upper Carrier)	384 kc	4 db

Receiver Noise Figure:

Space Station	8 db
Ground	2 db

Antenna Gain:

Space Station	0 db
Ground	44 db

Minimum Signal-To-Noise Ratio 15 db

UHF/S-Band Space-To-Ground Television Link

Frequency: 2290 Mc

Modulation: FM

RF Bandwidth 7 Mc

Receiver Noise Figure: 2 db

Antenna Gain:

Space Station	0 db
Ground	44 db

Minimum Signal-To-Noise Ratio 6 db

Table 4-13 (cont)  
COMMUNICATIONS AND TRACKING EQUIPMENT OPERATIONAL REQUIREMENTS

VHF Secondary Space-To-Ground Voice Link

Frequency:

Down	296.8 Mc
Up	259.7 Mc

Modulation: DSB/AM

RF Bandwidth:

Single Voice	7 kc
Double Voice	16 kc
(with 3.9 kc sidestop)	

Receiver Noise Figure:

Space Station	6 db
Ground	4 db

Space Station Antenna Gain: -2 db

Ground Antenna Gain:

Receive	18 db
Transmit	18 db

Minimum Signal-To-Noise Ratio 9 db

UHF Secondary Space-To-Ground Data Link

Frequency: 400-401 Mc

Modulation: PCM/FM

Data Rate:

Real-Time Links	20,000 bps (including biomed. data)
Delayed Time Link	44,000 bps

RF Bandwidth:

Real-Time Link	40 kc
Delay Time Link	88 kc

Receiver Noise Figure: 4 db

Table 4-13 (cont)  
COMMUNICATIONS AND TRACKING EQUIPMENT OPERATIONAL REQUIREMENTS

Space Station Ant. Gain:	-2 db
Ground Antenna Gain:	33 db
Minimum Signal-To-Noise Ratio:	15 db
VHF Space-To-Space Voice Link	
Frequency:	
To Space Station	259.7 Mc
From Space Station	296.8 Mc
Modulation:	DSB/AM
RF Bandwidth:	
Single Voice	7 kc
Double Voice	16 kc
(with 3.9 kc sidestep)	
Receiver Noise Figure:	6 db
Spacecraft Antenna Gain:	-3 db
Space Station Antenna Gain:	-2 db
Minimum Signal-To-Noise Ratio	9 db
UHF Space-To-Space Data Link	
Frequency:	400-401 Mc
Modulation:	PCM/FM
Data Rate:	5000 bps
RF Bandwidth:	10 kc
Receiver Noise Figure:	7 db
Spacecraft Antenna Gain:	-2 db
Space Station Antenna Gain:	-2 db
Minimum Signal-To-Noise Ratio	15 db

Table 4-13 (cont)  
COMMUNICATIONS AND TRACKING EQUIPMENT OPERATIONAL REQUIREMENTS

VHF Alternate Frequency Space-To-Space Data Link

Frequency:	184 Mc
Modulation:	PCM/FM
Data Rate:	5000 bps
RF Bandwidth:	10 kc
Receiver Noise Figure:	5 db
Spacecraft Antenna Gain:	3 db
Space Station Antenna Gain:	3 db
Minimum Signal-To-Noise Ratio	15 db

HF Exigency, Space-To-Ground Voice Link

Frequency:	15 Mc (assumed)
Modulation:	SSB/AM
RF Bandwidth:	3 kc
Sky Noise Temperature: (vis gnd ant)	$1.3 \times 10^{50} \text{K}$ (Equiv to Noise) Figure of 26 db
Receiver Noise Temperature	870°K with 0.9 eff'y ant)
Reflection and Scatter Loss:	30 db
Spacecraft Antenna Gain:	-3 db
Ground Antenna Gain:	+2 db
Minimum Signal-To-Noise Ratio	9 db

VHF Acquisition Aid Beacon

Frequency:	136 Mc
Modulation:	CW or PM
RF Bandwidth:	2 kc
Receiver Noise Figure:	4 db
Spacecraft Antenna Gain:	-4 db
Ground Antenna Gain:	14 db (assumed)
Minimum Signal-To-Noise Ratio	12 db

Table 4-13 (cont)  
COMMUNICATIONS AND TRACKING EQUIPMENT OPERATIONAL REQUIREMENTS

C-Band Transponder

Frequency:	5.7 Gc
Modulation:	Pulse
RF Bandwidth, up:	12 Mc
RF Bandwidth, down:	7 Mc
Transponder Receiver Sensitivity	-75 dbm
Spacecraft Antenna Gain:	0 db
Radar Peak Power Output:	250 kw
Radar Antenna Gain:	44 db
Radar Receiver Noise Figure:	7 db
Radar Minimum	
Signal-To-Noise Ratio	10 db

S-Band Transponder

Frequency:	2.7 Gc
Modulation:	Pulse
RF Bandwidth, up:	4 Mc
RF Bandwidth, down:	3 Mc
Transponder Receiver Sensitivity	80 dbm
Spacecraft Antenna Gain:	0 db
Radar Peak Power Output:	325 kw
Radar Antenna Gain:	36 db
Radar Receiver Noise Figure:	6 db
Radar Minimum	
Signal-To-Noise Ratio	10 db

Table 4-13 (cont)  
COMMUNICATIONS AND TRACKING EQUIPMENT OPERATIONAL REQUIREMENTS

UHF/S-Band Voice and Data Link (down)	Link Parameter	Gain db	Loss db			
Thermal Noise Power Density (Input Noise (Receiver Noise Figure + Sky + Antenna Noise)		204				
Receiver Miscellaneous Losses						3
Receiver Antenna Gain		44				1
Transmission Loss						166
Faraday Rotation Loss						3
Transmitter Antenna Gain						0
Transmitter Miscellaneous Losses						2
System Design (or fade) Margin						6
Required Receiver Signal-To-Noise Ratio						15
Detection Bandwidth			PRN	Voice	Lower Data	Upper Data
Modulation Loss (Max)			20	46	53	56
Transmitter Power			7	7	4	4
			223	249	253	256
			PRN	Voice	Lower Data	Upper Data
			-25	1	5	8
			223	249	253	256

Table 4-13 (cont)

COMMUNICATIONS AND TRACKING EQUIPMENT OPERATIONAL REQUIREMENTS

UHF/S-Band Television Link

<u>Link Parameter</u>	<u>Gain (db)</u>	<u>Loss (db)</u>
Thermal Noise Power Density	204	
RF Bandwidth		69
Input Noise (Receiver Noise Figure + Sky + Antenna Noise)		3
Receiver Miscellaneous Losses		1
Receiver Antenna Gain	44	
Required Receiver Signal-To- Noise Ratio		6
Transmission Loss		166
Faraday Rotation Loss		3
Transmitter Antenna Gain		0
Transmitter Miscellaneous Losses		2
System Design (or fade) Margin		6
Transmitter Power	8	
	<u>256</u>	<u>256</u>

UHF/400 MC Space-to-Space Data Link

<u>Link Parameter</u>	<u>Gain (db)</u>	<u>Loss (db)</u>
Thermal Noise Power Density	204	
RF Bandwidth		40
Input Noise (Receiver Noise Figure + Sky + Antenna Noise)		8
Receiver Miscellaneous Losses		1.5
Receiver Antenna Gain		2
Required Receiver Signal-To-Ratio		15
Transmission Loss		142
Antenna Cross Polarization Loss		3
Transmitter Antenna Gain		3
Transmitter Miscellaneous Losses		1.5
System Design (or fade) Margin		6
Transmitter Power	18	
	<u>222</u>	<u>222</u>

#### 4.2.4 Data Management and Displays

This section presents the requirements for the Data Management and Displays subsystems of the One- and Two-Compartment Laboratories, the Interim Station, and the Operational Station.

Data Management subsystems consist of the following major components:

- Processing equipment such as signal conditioners, converters, and computers to process data for transmission, display, or storage.
- Distribution equipment to route the processed data.
- Storage equipment for retention of data.

Display subsystems consist of 1) the visual aids (gages, digital read-outs, pictures, etc.) necessary to convey information to the crew, and 2) the controls (switches, knobs, etc.) necessary to operate the station.

##### 4.2.4.1 Description

The Data Management subsystems for the One- and Two-Compartment Laboratories use the Apollo hardware and supplement it with additional equipment to meet the needs of longer missions and greater experimental capability. Figures 4-22, -23, and -24 show the Data Management subsystems of the Apollo, the One-Compartment Laboratory, and the Two-Compartment Laboratories, respectively. Physical characteristics of the subsystems of the One- and Two Compartment Laboratories are given in Tables 4-14 and -15, respectively.

The Interim Station Data Management subsystem utilizes new equipment with greater data capacity and faster data processing rates. The basic bit rate is 100 to 400 kilobits/sec for the recorders and PCM telemetry equipment. Data storage capacity is 180 megabits/reel. Figure 4-25 shows a block diagram and Table 4-16 lists the physical characteristics.

The Operational Station Data Management subsystem is a threefold expansion of the Interim Station subsystem with new switching and interrupt



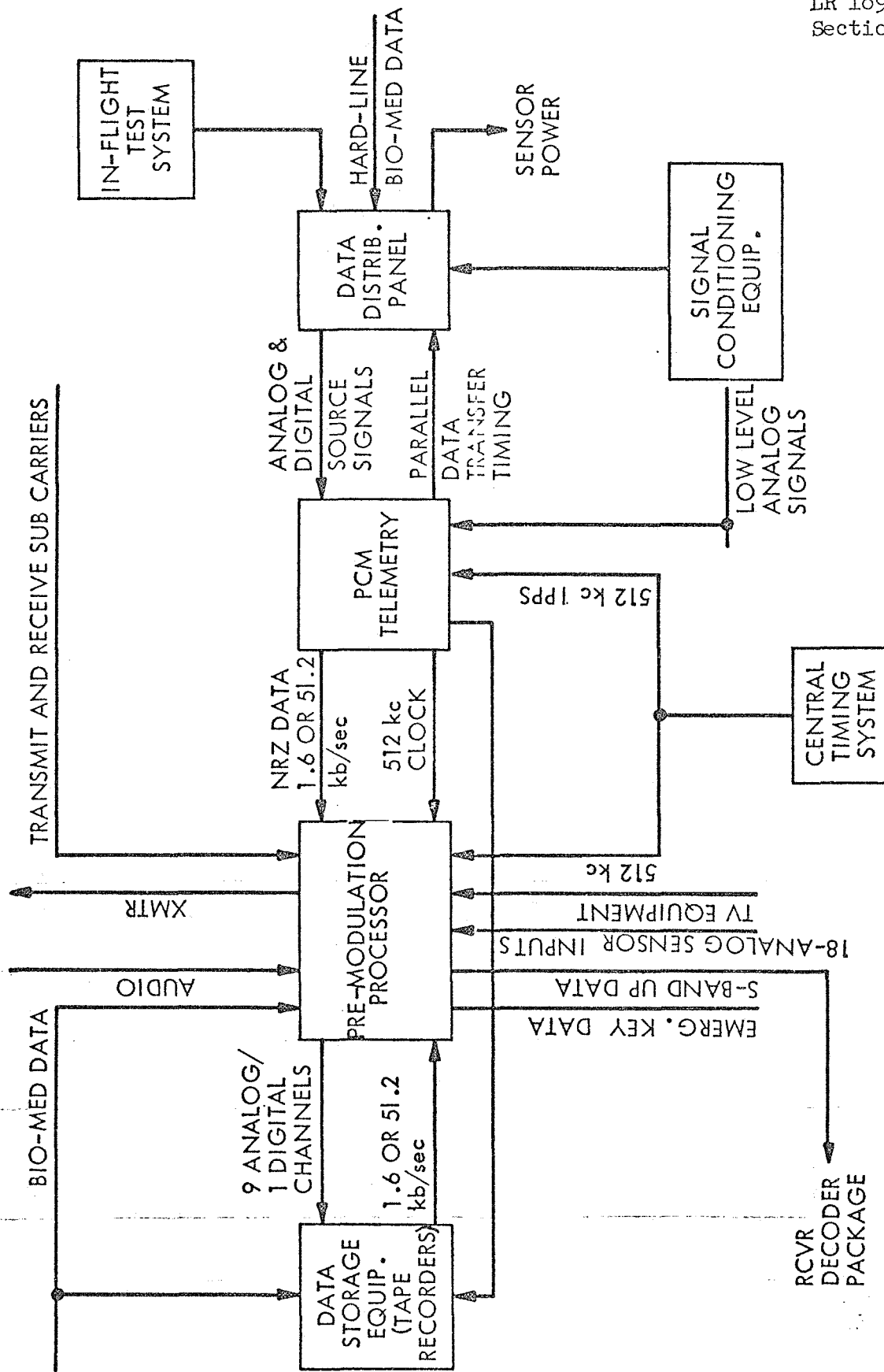


FIG. 4-22 BLOCK DIAGRAM-APOLLO DATA MANAGEMENT SUBSYSTEM

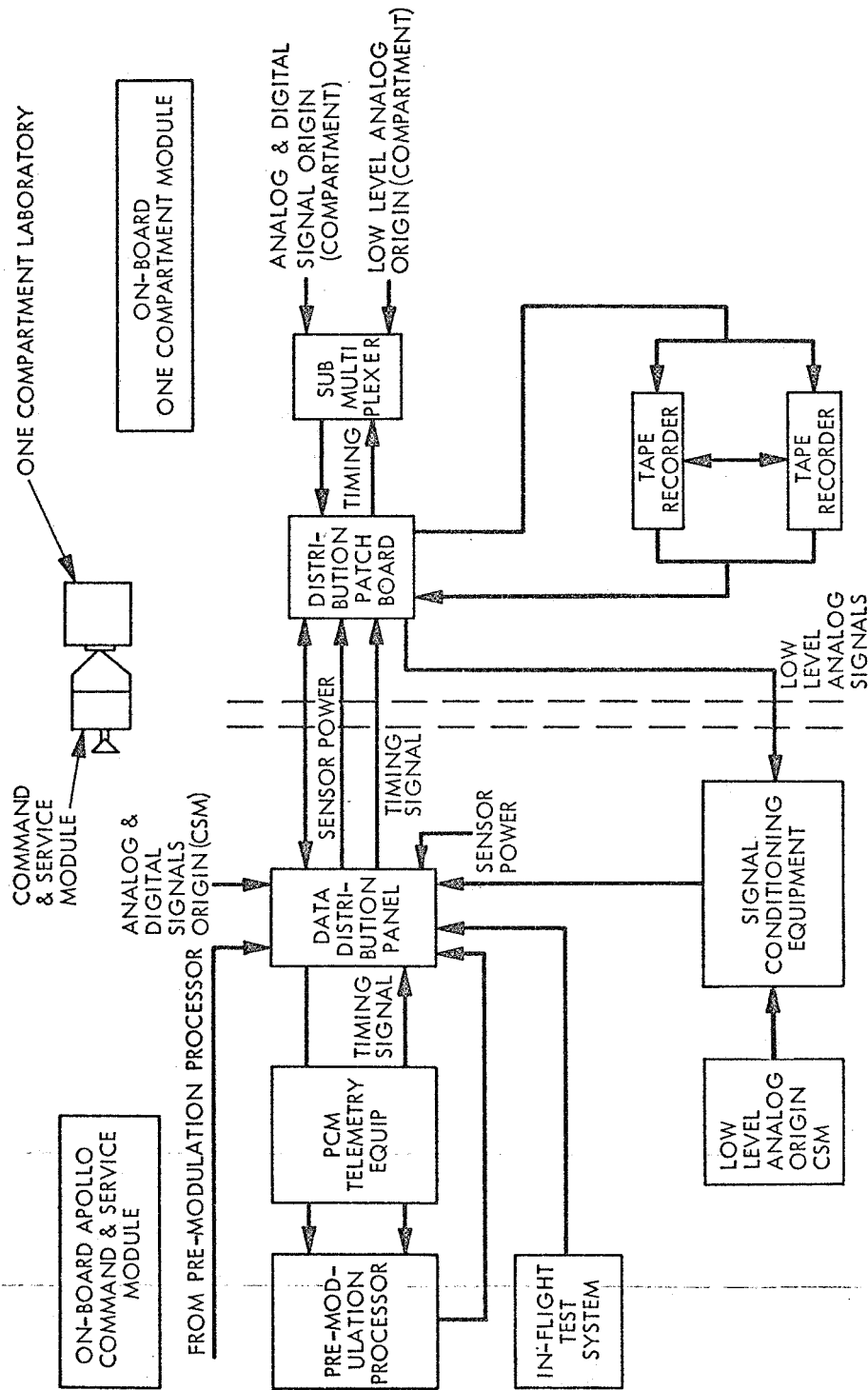


FIG. 4-23 BLOCK DIAGRAM, ONE-COMPARTMENT LABORATORY DATA MANAGEMENT SUBSYSTEM

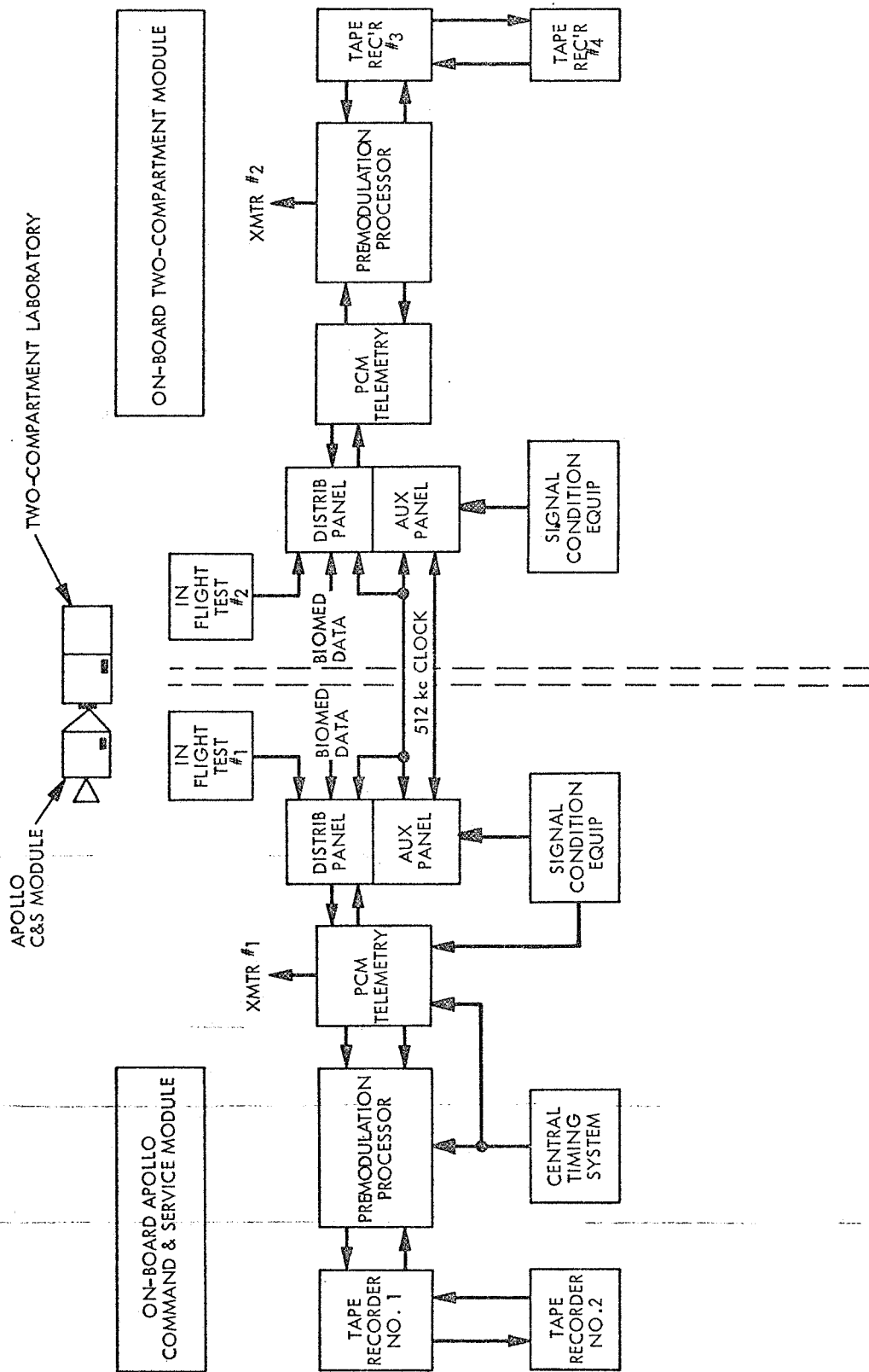


FIG. 4-24 BLOCK DIAGRAM, TWO-COMPARTMENT LABORATORIES DATA MANAGEMENT SUBSYSTEM

Table 4-14

PHYSICAL CHARACTERISTICS OF DATA MANAGEMENT SUBSYSTEM FOR THE  
ONE-COMPARTMENT DEPENDENT LABORATORY

Component	Units	Weight (lb)	Volume (ft <sup>3</sup> )	Power (Watts)
Signal Conditioner	1	40.0	0.45	75.0
PCM Telemetry	1	42.0	0.4	9.0
Pre-Modulator Processor	1	15.3	0.32	10.0
Data Storage	2	42.2	1.2	34.0
Central Timing Unit	1	2.0	0.2	4.0
In-Flight Test	1	10.0	1.0	15.0
Total		151.5	3.57	147.0

Table 4-15

PHYSICAL CHARACTERISTICS OF DATA MANAGEMENT SUBSYSTEM FOR THE  
TWO-COMPARTMENT LABORATORIES

Component	Units	Weight (lb)	Volume (ft <sup>3</sup> )	Power (Watts)
Signal Conditioner	2	80.0	0.90	150.0
PCM Telemetry	2	84.0	0.8	18.0
Pre-Modulator Processor	2	30.6	0.64	20.0
Data Storage	4	84.4	2.4	68.0
Central Timing Unit	1	2.6	0.3	4.0
In-Flight Test	2	20.0	2.0	30.0
Switching and Routing	1	3.5	0.5	1.3
Total		305.1	7.54	291.3

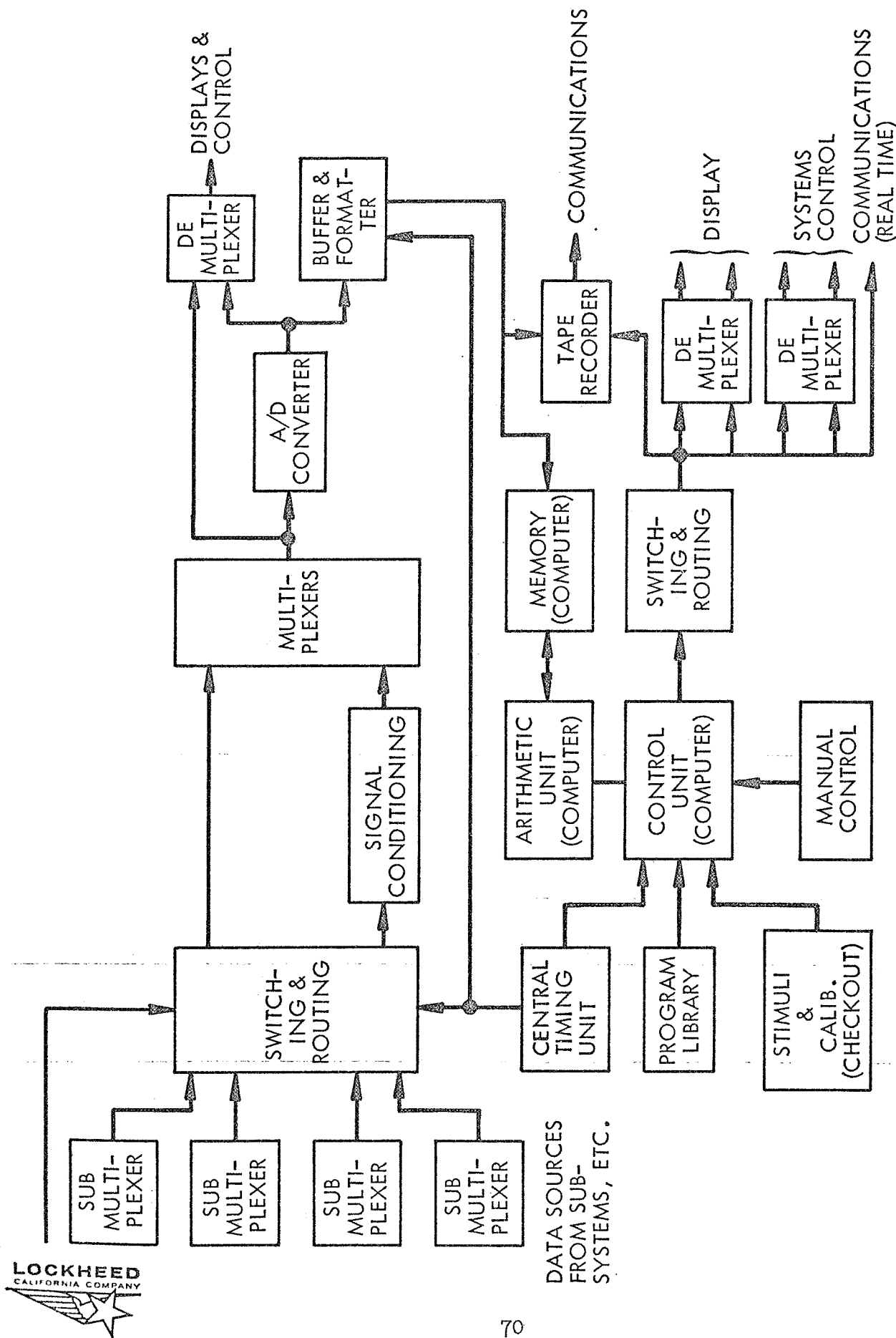


FIG. 4-25 BLOCK DIAGRAM, INTERIM STATION DATA MANAGEMENT SUBSYSTEM

Table 4-16

PHYSICAL CHARACTERISTICS OF DATA MANAGEMENT SUBSYSTEM FOR THE  
INTERIM STATION

Subsystem	Units	Weight (lb)	Volume (ft <sup>3</sup> )	Power (watts)
Sub-Multiplexers	4	7.0	0.05	4.0
Switching & Routing	2	7.0	0.6	2.5
Signal Conditioner	4	9.4	0.53	1.2
A/D Converters	2	10.0	1.0	20.0
Buffer & Formatter	1	5.0	0.7	20.0
Computer	1			
Memory		18.0	0.4	68.0
Arithmetic Unit		15.0	0.2	0.33
Control Unit		8.0	0.3	0.13
Tape Recorder	2	40.0	1.5	50.0
De-multiplexers	2	3.5	0.03	2.0
Power Supply	1	15.0	1.0	10.0
Calib. Unit	1	10.0	1.0	15.0
Multiplexers	2	2.0	0.4	8.0
Timing Unit	1	2.0	0.2	4.0
Total		151.9	7.91	205.2

equipment added to allow computer operation from any module. In addition to greatly increasing data storage capacity, this innovation enhances reliability. Figure 4-26 shows a functional interface diagram and Table 4-17 lists the physical characteristics.

Displays and controls in the Apollo are intended only to portray operational status of the station inasmuch as the Apollo is not an experimental laboratory. The One and Two Compartment Laboratories rely heavily on Apollo equipment but some new displays and controls are necessary for them because they are designed for experimentation and because some of their subsystems have new requirements. The following modifications and additions are necessary to make the Apollo displays and controls adequate for the One Compartment Laboratory:

- The Stabilization and Control, Navigation and Guidance, and Communications displays will be changed to reflect changes in these subsystems.
- The data processing and environmental control displays will be duplicated in the laboratory area. The data processing section will show selection of tape recorders and tape recorder status.
- Water management displays will be added.
- Special experimental displays will be added.

The Two Compartment Laboratories will utilize displays and controls from the One Compartment Laboratory with the following additions:

- Displays and controls for the solar array electric power source.
- The Independent Laboratory only of the Two Compartment Laboratories, will have a rendezvous display panel to show incremental velocity, range rate, and propellant status for implementation of the rendezvous phase.

The Interim and Operational Stations will have modularized display panels usable, with slight modifications, for both configurations. The status displays and controls will be similar to those used on the One and Two Compartment Laboratories; however, there may be duplication of displays in either station to provide monitoring capability from more than one compartment or module. Special experimental displays will not be defined at this time because of the lack of final definition of the experimental program.



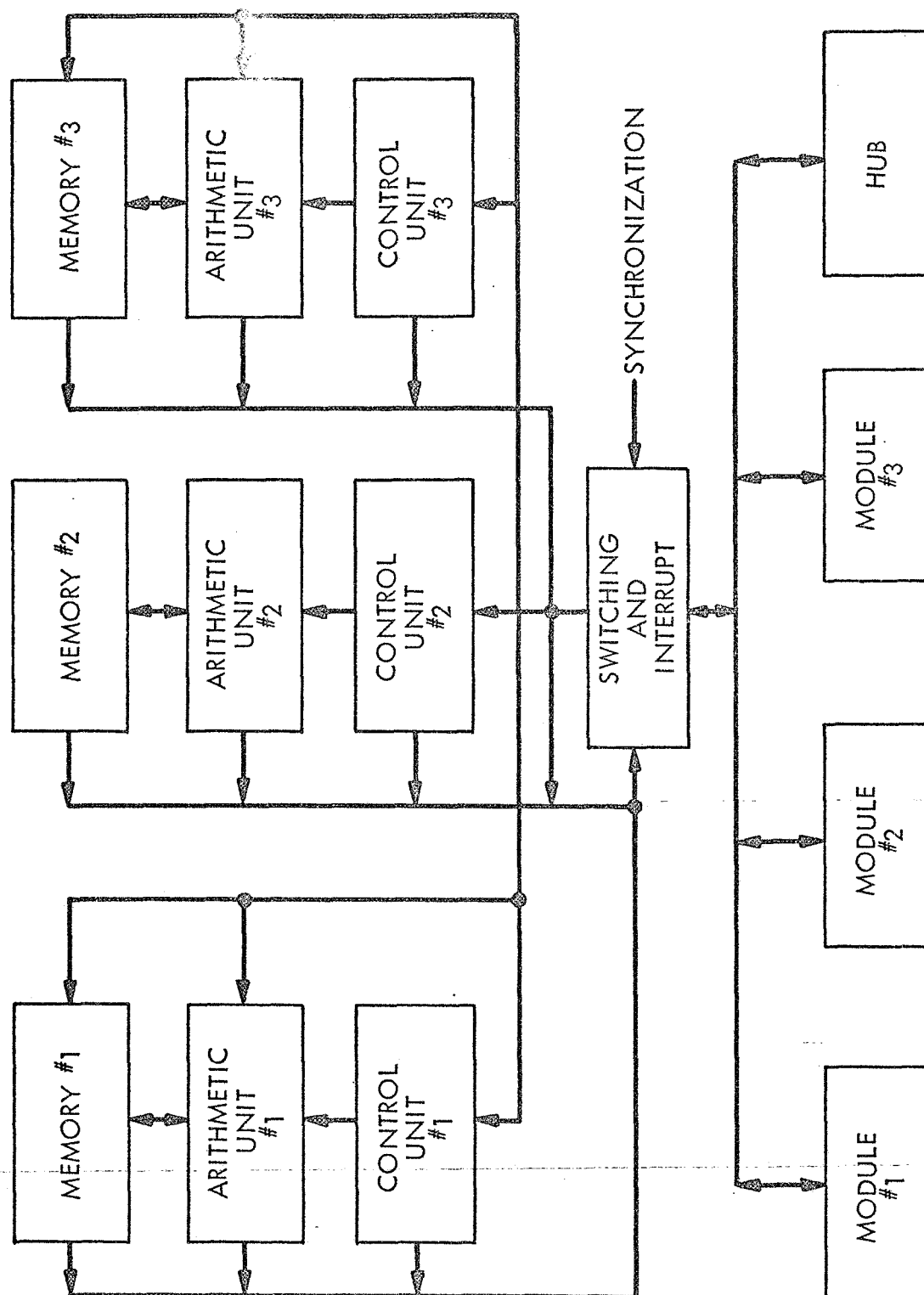


FIG. 4-26 FUNCTIONAL INTERFACE BLOCK DIAGRAM, OPERATIONAL STATION DATA MANAGEMENT SUBSYSTEM

Table 4-17

PHYSICAL CHARACTERISTICS OF DATA MANAGEMENT SUBSYSTEM FOR THE  
OPERATIONAL STATION

Item	Units	Weight (lb)	Volume(ft <sup>3</sup> )	Power (watts)
Sub-Multiplexers	12	21.0	0.15	12.0
Switch & Routing	7	25.0	1.5	8.8
Signal Conditioner	15	35.0	2.0	5.0
A/D Converter	6	30.0	3.0	60.0
Buffer & Formatter	3	15.0	2.0	60.0
Computer	3			
Memory		55.0	1.0	200.0
Arithmetic		45.0	0.5	100.0
Control		30.0	2.0	40.0
Multiplexers	8	23.0	1.5	30.0
Tape Recorders	6	113.0	3.8	150.0
Power Supply	3	45.0	3.0	30.0
Calibration Unit	3	30.0	3.0	45.0
Demultiplexers	6	10.5	1.0	6.0
Timing Unit	1	2.0	0.2	4.0
Total		479.5	24.65	750.8

#### 4.2.4.2 Performance Requirements

Performance requirements applicable to Apollo displays and controls shall apply to the One- and Two-Compartment Laboratories.

Data handling capability on the Interim and Operational Stations shall be 100 to 400 kilobits/sec with the potential for expansion to approximately 500 kilobits/sec for both recorders and telemetry equipment depending on the capability of the ground tracking stations. Data storage capacity shall be 180 megabits/reel.

#### 4.2.4.3 Design Requirements

The Data Management and Displays subsystems shall meet the general requirements of paragraph 4.2 of this report.

The figures listed below shall govern the arrangements of the Data Management subsystems and the tables listed indicate the weight, volume, and power goals of the components.

<u>Space Station</u>	<u>Figure No.</u>	<u>Table No.</u>
One-Compartment Laboratory	4-23	4-14
Two-Compartment Laboratories	4-24	4-15
Interim Station	4-25	4-16
Operational Station	4-26	4-17

Data handling rate capabilities of the Interim and Operational Stations shall be consistent with the capabilities of the ground tracking stations.

When data handling components are duplicated within a subsystem, they shall be functionally arranged so that they may be used interchangeably.

Displays shall be modularized as soon as possible in the development of the family of space stations. Every attempt shall be made to standardize status display panels so that they may be used on the greatest number of stations.

#### 4.2.5 Navigation and Guidance

Requirements for the One-Compartment Dependent Laboratory; the Two Compartment Independent, Polar, and Synchronous Laboratories; the Interim Station; and the Operational Station are presented in this section.

The Navigation and Guidance subsystems consist of the following components:

- Sensors to determine space station position, attitude, velocity, acceleration, and time. To obtain these parameters, horizon sensors, star trackers, inertial platforms, gyros, accelerometers, and clocks are utilized.
- Computers to process the information received from the sensors.
- Electronic devices to condition computer signals so that they will be accepted by the displays and by the stabilization and control subsystem.

Navigation and guidance subsystems may also be arranged to accept inputs from ground tracking stations.

##### 4.2.5.1 Description

The subsystems are arranged functionally for the various vehicle configurations as shown in Figures 4-27, -28, -29, and -30. The components and their weights, volumes, and power requirements are listed in Table 4-18. Utilization of Apollo hardware is shown in Table 4-19. Two navigation methods are employed for the Modular Multipurpose Space Station family depending on the navigational accuracy required by the mission. They are:

- Ground Updating Navigation. Information received periodically from the ground is continuously extrapolated by an on-board computer between the updating periods. The One-Compartment Laboratory, the Two-Compartment Independent, and the Synchronous Orbit Laboratory utilize this low accuracy subsystem.
- Autonomous Navigation. An inertial platform and a star tracker aboard the station convey information to an on-board computer for direct position and velocity data. The Polar Orbit Laboratory, the Interim Station, and the Operational Station employ this high accuracy subsystem.\*

\*The Independent Laboratory is utilized as a proving ground for the autonomous navigation system.

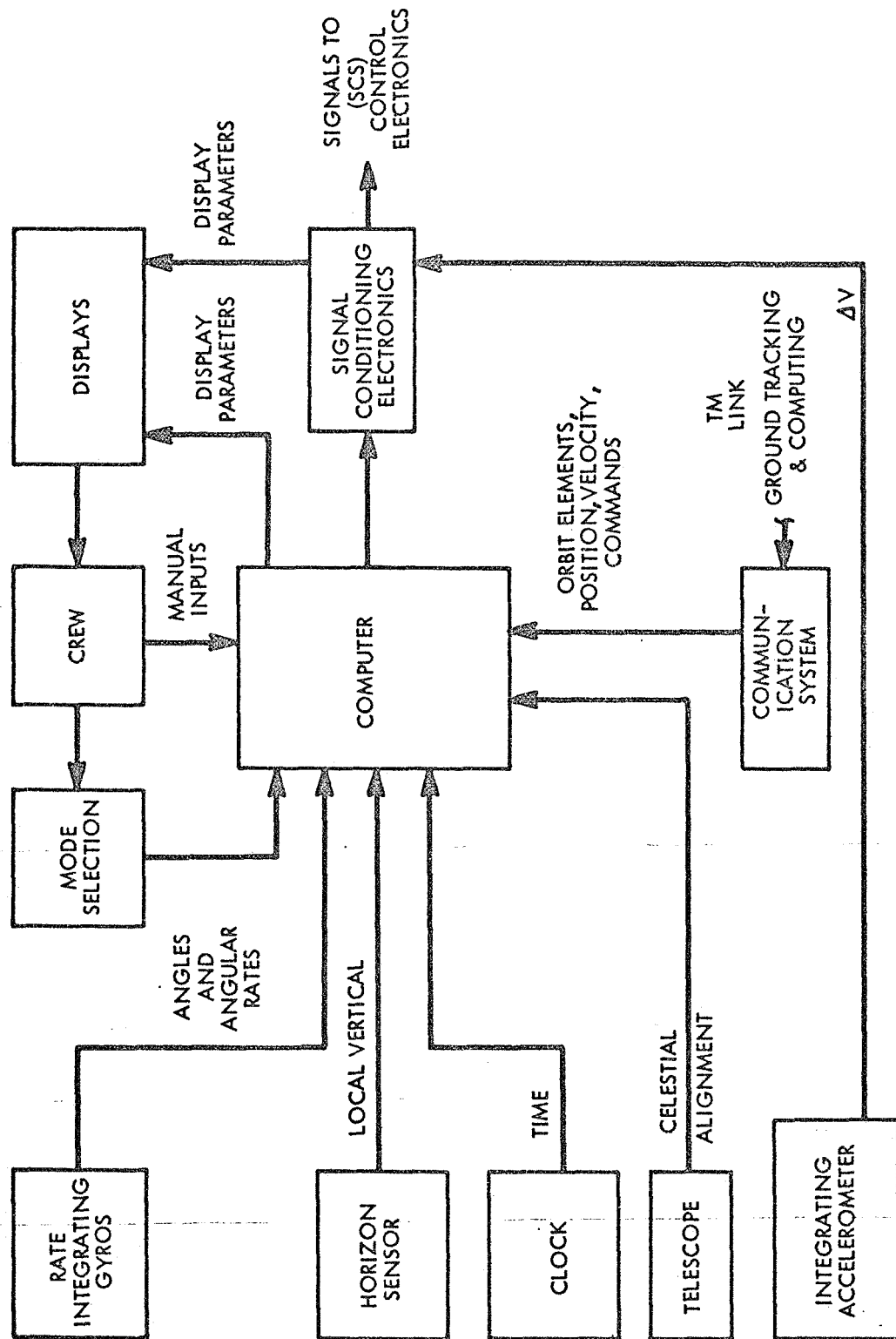


FIG. 4-27 FUNCTIONAL DIAGRAM, GUIDANCE AND CONTROL SUBSYSTEM - ONE-COMPARTMENT  
DEPARTMENT LABORATORY AND TWO-COMPARTMENT SYNCHRONOUS ORBIT LABORATORY

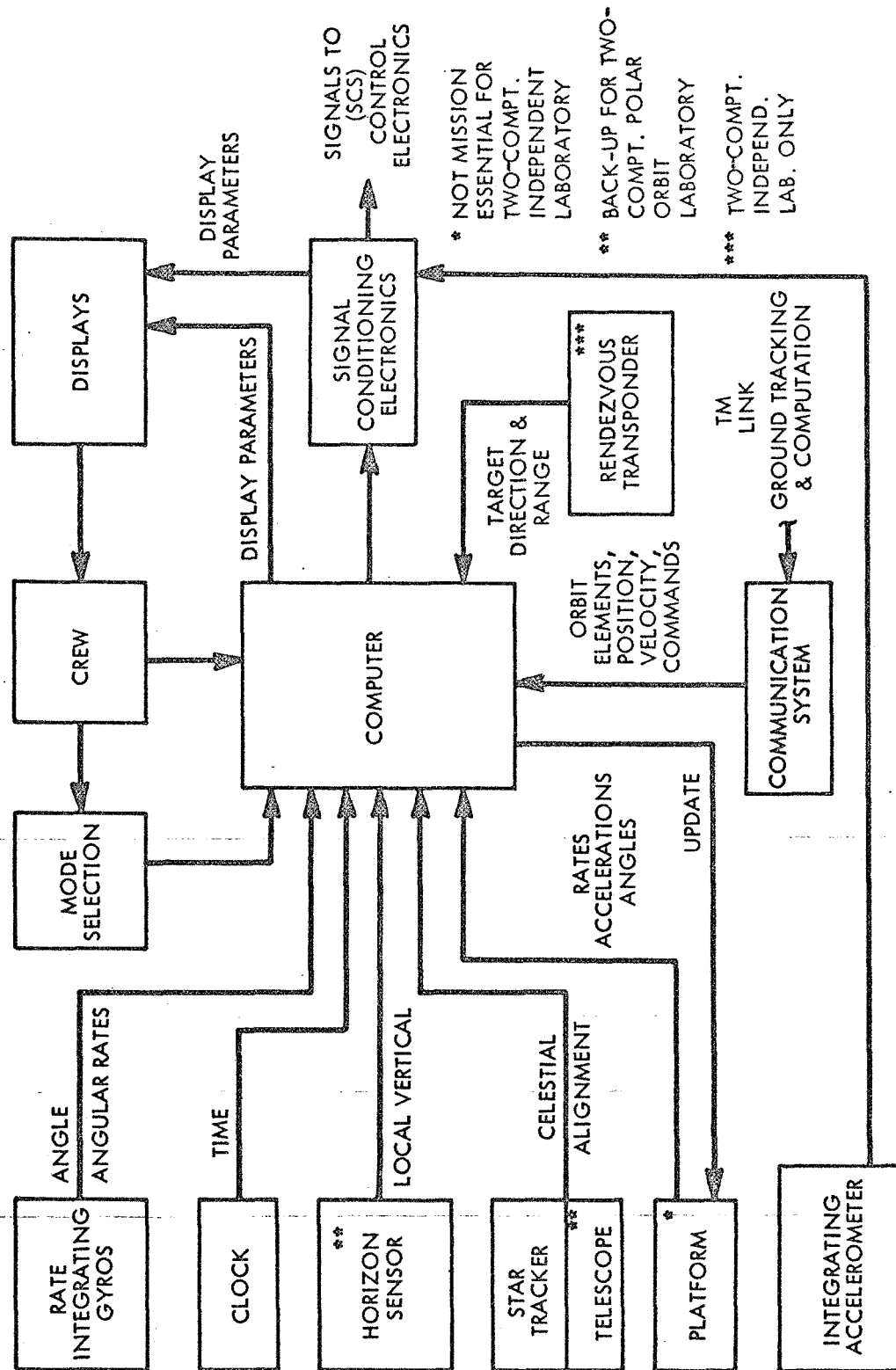


FIG. 4-28 FUNCTIONAL DIAGRAM, GUIDANCE AND CONTROL SUBSYSTEM TWO-COMPARTMENT INDEPENDENT AND POLAR ORBIT LABORATORIES



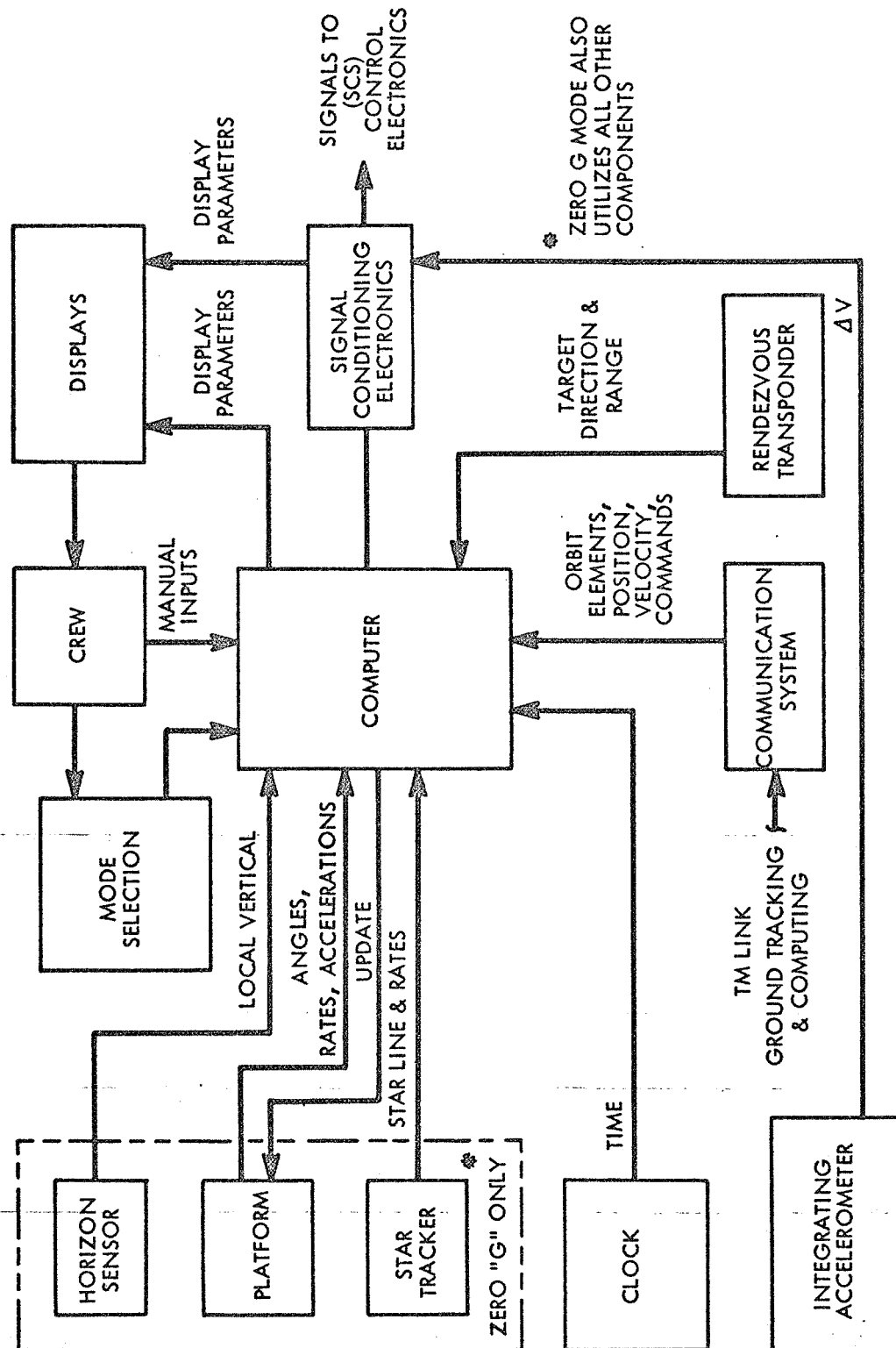


FIG. 4-30 FUNCTIONAL DIAGRAM, GUIDANCE AND CONTROL SUBSYSTEM -  
OPERATIONAL SPACE STATION (ROTATING)



Table 4-18  
EQUIPMENT LIST FOR THE NAVIGATION AND GUIDANCE SUBSYSTEM

Station			One- Compartment Laboratory			Two-Compartment Laboratories									Interim Station			Operational Station		
Component			Independent			Polar Orbit			Synchronous Orbit			Interim Station			Operational Station					
lb	watt	ft <sup>3</sup>	Wt	Pwr	Vol	Wt	Pwr	Vol	Wt	Pwr	Vol	Wt	Pwr	Vol	Wt	Pwr	Vol			
Computer			65	100	1.9	50	70	1.5	65	100	1.9	50	70	1.5	50	70	1.5			
Platform			-	-	-	40	200	0.7	-	-	-	40	200	0.7	40	200	0.7			
Rate Integrating Gyro			35	30	1.0	35	30	1.0	35	30	1.0	-	-	-	-	-	-			
Signal Conditioning & Electronics & Power Supply			91	100	2.6	40	60	1.0	91	100	2.6	40	60	1.0	60	100	1.2			
Integrating Accelerometer			4	5	0.1	4	5	0.1	4	5	0.1	6	7	0.1	6	7	0.1			
Horizon Sensor			10	10	0.3	10	10	0.3	10	10	0.3	10	10	0.3	10	10	0.3			
Scanning Telescope			27	-	0.4	27	-	0.4	27	-	0.4	-	-	-	-	-	-			
Star Tracker			-	-	-	6	10	0.2	-	10	0.2	-	10	0.2	6	10	0.2			
Rendezvous Transponder			-	-	-	40	-	-	-	-	-	40	-	-	80	-	-			
Totals			232	245	6.3	252	385	5.2	278	455	7.2	245	357	3.8	252	397	4.0			

NOTE: 1. The above figures do not include weights for spares, display instruments, mounting, cabling etc.

NOTE: 1. The above figures do not include weights for spares, display instruments, mounting, cabling etc.

Table 4-19  
MAJOR COMPONENT EVOLUTION OF THE NAVIGATION AND GUIDANCE SUBSYSTEM

Space Station Component	One- Compartment Dependent Laboratory	Two-Compartment Laboratories			Interim Station	Operational Station
		Independent	Polar Orbit	Synchronous Orbit		
Computer	Apollo	New Development Greater Capacity With Micro- electronics	Apollo	Apollo	Same as Two- Compartment Independent Laboratory	Centralized But Using Previous Technology
Platform	None	New Development Long Life * Bearings	Same as Two- Compartment Independent Laboratory	None	Same as Two- Compartment Independent Laboratory	Same as Two- Compartment Independent Laboratory
Rate Integrating Gyro	Apollo	Apollo + Spares	Apollo *	Apollo + Spares	None	None
Signal Conditioning Electronics	Apollo	New Development Micro- Electronics	Apollo	Apollo	New But Using Previous Technology	New But Using Previous Technology
Integrating Accelerometer	Apollo	Apollo	Apollo	Apollo	New - Minor Development	Same as In- terim Station
Horizon Sensor	New	Same as One- Compartment Dependent Laboratory	Same as One- Compartment Dependent Laboratory	Same as One- Compartment Dependent Laboratory	Same as One- Compartment Dependent Laboratory	Same as One- Compartment Dependent Laboratory
Alignment	Apollo	Apollo	Apollo	Apollo	None	None
Star Tracker	None	New Development	Same as Two- Compartment Independent Laboratory	None	Same as Two- Compartment Independent Laboratory	Same as Two- Compartment Independent Laboratory

\* Not Mission Essential

#### 4.2.5.2 Performance Requirements

The Navigation and Guidance subsystems shall meet the requirements listed in Table 4-20.

Horizon sensors and star trackers shall, as a minimum, meet the 1965 accuracies shown below, and efforts shall be made to attain the accuracies forecast for the 1970 period.

Table 4-20  
NAVIGATION & GUIDANCE SUBSYSTEM ACCURACIES

ITEM	Navigation Method	
	Ground Updating	Autonomous Navigation
Downrange Position Error, ft Velocity Error, ft/sec	3000 1.5	1000 1.0
Out of Plane Position Error, ft Velocity Error, ft/sec	3000 1.5	1000 1.0
Altitude Position Error, ft Velocity*Error, ft/sec	1000 0.2	500 0.2
*Rate of Change of Altitude		
ITEM	Accuracies for	
	1965	1970
Horizon Sensor accuracy per axis	18 arc min	5 arc min
Star Tracker accuracy per axis	10 arc sec	5 arc sec

Target reliabilities for the horizon sensors and star trackers shall be 7,000 to 10,000 hours Mean-Time-Between-Failures (MTBF) for the 1970 period and the inertial platforms shall be capable (in the 1970 period) of operating continuously for one year without failure.

Gyros for inertial platforms shall be capable of exhibiting a drift rate of no more than 0.1 deg/hr during the 1965 period. Target drift rate for the 1975 period shall be 0.01 deg/hr.

Target reliability for digital computers during the 1970 period shall be 20,000 hours MTBF.

#### 4.2.5.3 Design Requirements

Navigation and guidance subsystems shall meet the general requirements stated in Section 4.2.

The subsystems for the various stations shall be arranged as shown in Figures 4-27, -28, -29, and -30.

Target weights and volumes for components of the subsystems shall be as shown in Table 4-18.

The subsystem of the Two Compartment Independent Laboratory shall include components peculiar to the Operational Station so that the suitability of these components may be demonstrated at an early stage in the development of the Modular Multipurpose Space Station family.

The utilization of microminiaturization in electronic circuitry shall be pursued diligently to achieve higher reliability and reduced weight.

The Navigation and Guidance subsystems shall be compatible with the GOSS network.

#### 4.2.6 Stabilization and Control

Performance and design requirements of stabilization and control subsystems of the One- and Two-Compartment Laboratories, the Interim Station, and the Operational Station are presented in this section along with brief descriptions.

Stabilization and control subsystems consist in general of the following components:

- Attitude sensors
- Rate gyros to determine accelerations
- Electronics packages to process attitude and rate information
- Mechanical devices such as actuators to transmit movement to, or actuate corrective devices such as propulsion engines
- Inertia wheel attitude stabilizers (control moment gyros)
- Dynamic and static balance devices such as controllable water ballast systems.

In addition, stabilization and control subsystems (SCS) utilize the propulsion subsystem engines to circularize the orbit, maintain altitude, spin and de-spin the stations (when applicable), and correct the attitude of the stations.

##### 4.2.6.1 Description

The One- and Two-Compartment Laboratories utilize Apollo SCS components (see Table 4-21) supplemented in some cases by new types of equipment added for test purposes. The Interim and Operational Stations, because of their size, mission duration, and operational requirements, incorporate all new components in the SCS. The components for the various stations are listed in Table 4-22. The subsystems are functionally arranged as shown in Figures 4-31 and -32.

##### 4.2.6.2 Performance Requirements

The Stabilization and Control Subsystem shall meet as a minimum, the performance requirements of Tables 4-23, -24, and -25. The control requirements imposed by experiments, Table 4-26, shall be used as

Table 4-21  
CHARACTERISTICS OF APOLLO SCS COMPONENTS

Apollo SCS Major Components	Characteristics	Function	Location in Apollo	Nomenclature	Location in Space Stations
X - Axis Accelerometer	Servo-rebalanced pendulous accelerometer	Data for $\Delta V$ Display	Lower Equipment Bay	Part of G & N input, processed in G & N Signal Conditioning	With spare com- ponents to be integrated with installations to facilitate main- tenance
Body-Mounted Attitude Gyro	Single degree of freedom integrating gyro	Attitude or rate sensor	Lower Equipment Bay	Part of G & N input, processed in G & N Signal Conditioning	
Rate Gyros	Angular rate gyro	Vehicle angular rate feedback for Stabilization	Lower Equipment Bay	Rate Gyros	
Attitude Gyro Coupler Unit	Computer	Computes the solar angle attitudes and attitude errors	Lower Equipment Bay	Control Electronics	
Pseudo-rate pulse modulator	Functional Pulsing logic	Improve fuel economy	Lower Equipment Bay	Control Electronics	
Jet Selection Logic	Digital computer	Signals to reaction engines	Lower Equipment Bay	Control Electronics	
Displays	Flight Director Attitude Indicator, SCS Control Panel, $\Delta V$ Display, Attitude set display	Show Attitude, attitude error, angular Control Mode Selection Velocity Control	System Control and Display Panel	Display Control Mode Selection	System Control and Display Panel
Controllers	Mechanical to Electrical Transducer	Manual attitude control (Pitch, yaw, roll rate command)	System Control and Display Panel	Manual Controller	System Control and Display Panel

Table 4-22  
MAJOR COMPONENT REQUIREMENTS FOR THE MODULAR SPACE STATION STABILIZATION & CONTROL SUBSYSTEM

Station Component	One-Compartment Dependent Laboratory	TWO-COMPARTMENT LABORATORIES			Interim Station	Operational Station
		Independent	Polar Orbit	Synchronous Orbit		
Control Electronics	Apollo	New Development Micro-Elect $\Delta$	Apollo	Apollo	Same as $\Delta$ Optimized	New but using Previous Technology
Rate Gyro	Apollo	New Development Gas Bearing $\Delta$	Apollo plus Spares	Apollo plus Spares	Same as $\Delta$	Same as $\Delta$ plus spares
Control Moment Gyro (CMG)	None	New Development Small Size $\Delta$	None	None	Larger Version of $\Delta$ Longer Life	Both Large & Small as in $\Delta$ and Interim Station
Accelerometer	None	None	None	None	None	Radial Acceleration Minor Development
Sun Sensor	None	None	None	None	New Minor Develop- ment	Same as Interim Station
Balance Motor	None	None	None	None	None	New Develop- ment
Balance Pump	None	None	None	None	None	New Development

Table 4-23  
STABILIZATION AND CONTROL PERFORMANCE REQUIREMENTS FOR THE ONE- AND TWO-COMPARTMENT LABORATORIES

OPERATION	ATTITUDE CONTROL & STABILIZATION FUNCTION	ONE-COMPARTMENT DEPENDENT LABORATORY	TWO-COMPARTMENT LABORATORIES		
			Independent	Polar Orbit	Synchronous Orbit
Initial Orbit Injection and Circularization	Stabilize Body Angular Rates - All Axes	0.1 deg/sec	0.1 deg/sec max.	0.1 deg/sec	By S-IVB
	Orient to Commanded Thrust Vector	$\pm 0.5$ deg	$\pm 0.5$ deg	$\pm 0.5$ deg	
Orbit Maintenance	Stabilize Body Angular Rates - All Axes	Not Required	0.1 deg/sec	0.1 deg/sec	Not Required
	Orient to Commanded Thrust Vector	Not Required	$\pm 0.5$ deg	$\pm 0.5$ deg	
Manned Orbital Operations	Stabilize Body Angular Rates - All Axes	0.5 deg/sec min.	0.5 deg/sec min.	0.5 deg/sec min.	0.5 deg/sec min.
	Routine Operations				
	Experiment Operations				
	Majority Critical				
	Orient to a Commanded Attitude	0.1 deg/sec	0.1 deg/sec	0.1 deg/sec	0.1 deg/sec
	Routine Operations				
	Experiment Operation				
	Majority Critical				
		$\pm 5.0$ deg	$\pm 5.0$ deg	$\pm 5.0$ deg	$\pm 5.0$ deg
		$\pm 0.5$ deg	$\pm 0.5$ deg	$\pm 0.5$ deg	$\pm 0.5$ deg



Table 4-24  
STABILIZATION AND CONTROL PERFORMANCE REQUIREMENTS  
FOR THE INTERIM MODULAR SPACE STATION

OPERATION	ATTITUDE CONTROL AND STABILIZATION FUNCTION	REQUIREMENT
Initial Orbit Circularization (Unmanned)	Stabilize Body Angular Rates Orient to Commanded Thrust Vector	0.1 deg/sec +0.5 deg
Unmanned Operation Before Initial Rendezvous and Docking	Orientation	Longitudinal Axis Perpendicular to Sun Line within 10 deg
Rendezvous and Docking	Align to a Commanded Orientation Stabilize Body Angular Rates	+0.5 deg -0.1 deg/sec
Manned Zero G Operation Orbit Maintenance Normal Operation Experimental Modes	Stabilize Body Angular Rates Orient to Commanded Thrust Vector Orientation Stabilize Body Angular Rates Orientation Stabilize Body Angular Rates	0.1 deg/sec +0.5 deg Solar +5 deg 0.5 deg/sec Optional down to +0.1 deg Optional down to 0.05 deg/sec

Table 4-25  
STABILIZATION AND CONTROL PERFORMANCE REQUIREMENTS FOR THE OPERATIONAL MODULAR SPACE STATION

OPERATION	ATTITUDE CONTROL AND STABILIZATION FUNCTION	REQUIREMENT
Initial Orbit Circularization (Unmanned)	Stabilize Body Angular Rates Orient to a Commanded Thrust Vector	0.1 deg/sec $\pm 0.5$ deg
Unmanned Operation Before Initial Rendezvous and Docking	Orientation	X axis perpendicular to sun line within 10 deg and rotating at 0.1 rpm (Estimated Max Duration 30 days)
Rendezvous and Docking (Unmanned)	Align to a Commanded Orientation Stabilize Body Angular Rates	$\pm 0.5$ deg 0.1 deg/sec
Manned Zero G Modes	-----	Optional (see Fig. 4-32)
Unfolding Spin-up	Orientation Pointing Accuracy	X axis solar orientation within 10 deg max. at design not more than 5 deg cone angle
Rotating (Solar Orientation)	Pointing Accuracy Attitude Stability Orbit Maintenance Balance Control	Within 0.1 deg if required Cone 1/2 angle 0.1 deg Operated when the spin axis is aligned with the orbit velocity vector Consistent with attitude stability

Table 4-26  
CONTROL REQUIREMENTS IMPOSED BY VARIOUS EXPERIMENTS

LOCKHEED NO.	EXPERIMENT TITLE	ANGULAR ORIENTATION ACCURACY	ANGULAR RATE ACCURACY	OTHER CONTROL REQUIREMENTS
303A	Horizon Spectrometry	0.01 to 0.03 deg.		
307	Albedo Level Measurement	1 arc-sec		(Planetary Albedo) Hold for 15 Min.
351	Multispectral Sensing	0.01 to 0.03 deg.		
		1 arc-sec		Hold for 15 Min.
352	Photography		$0.5 \times 10^{-4}$ to $1 \times 10^{-4}$ Rad/sec	
		1 arc-sec		
601	Laser Communication	1 arc-sec	$0.01 \frac{\text{deg}}{\text{hr}}$ all axes	Location $\pm 1$ n.mile
691	Advanced Photographic Systems		$10 \frac{\text{arc-sec}}{\text{sec}}$	
728	Jet Stream Monitoring		$1 \frac{\text{arc-min}}{\text{sec}}$	

ONE-COMPARTMENT LABORATORY, TWO-COMPARTMENT LABORATORIES,  
INTERIM STATION, OPERATIONAL STATION (ZERO G MODE ONLY)

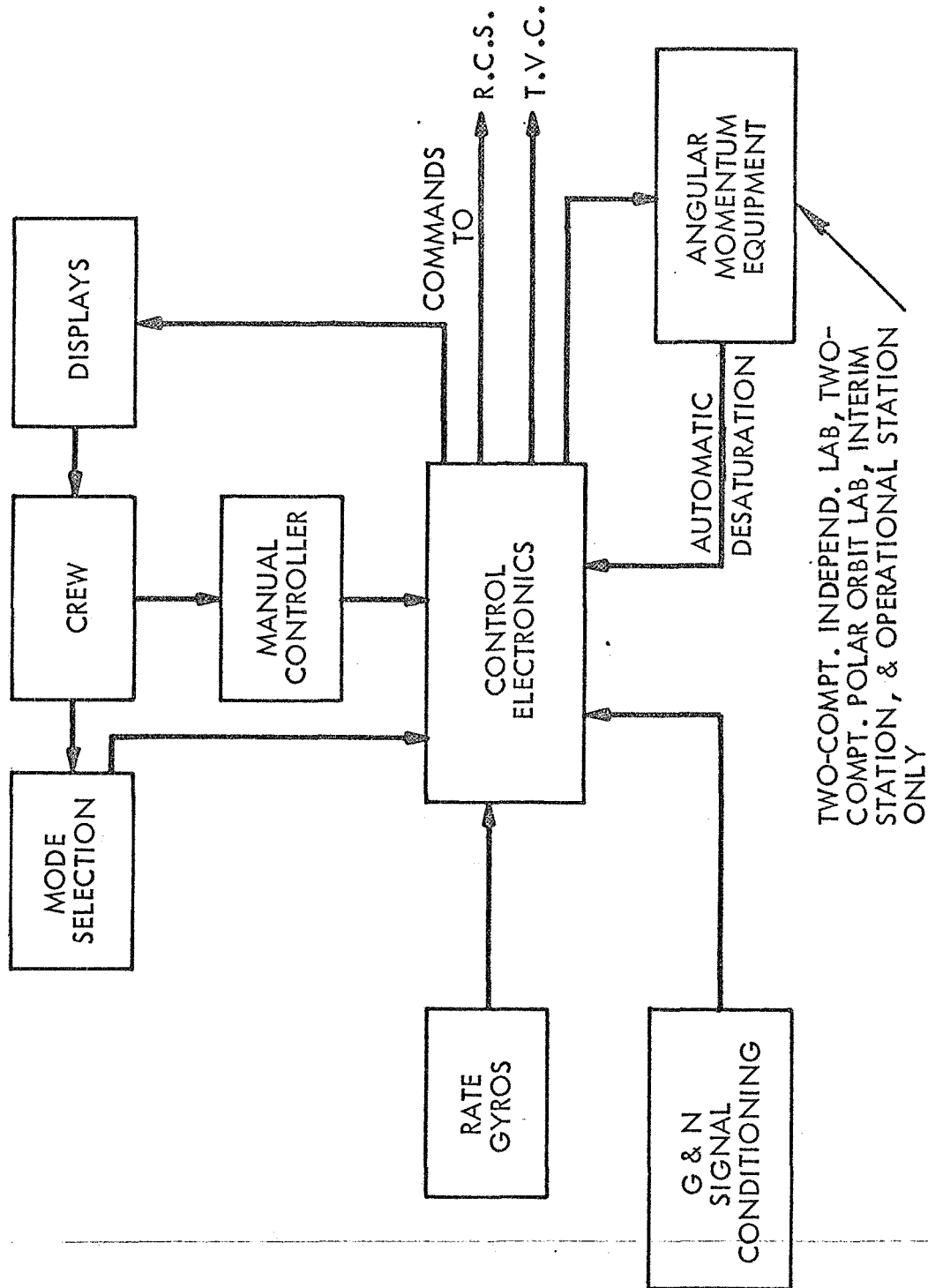


FIG. 4-31 FUNCTIONAL DIAGRAM-ATTITUDE CONTROL & STABILIZATION SUBSYSTEM

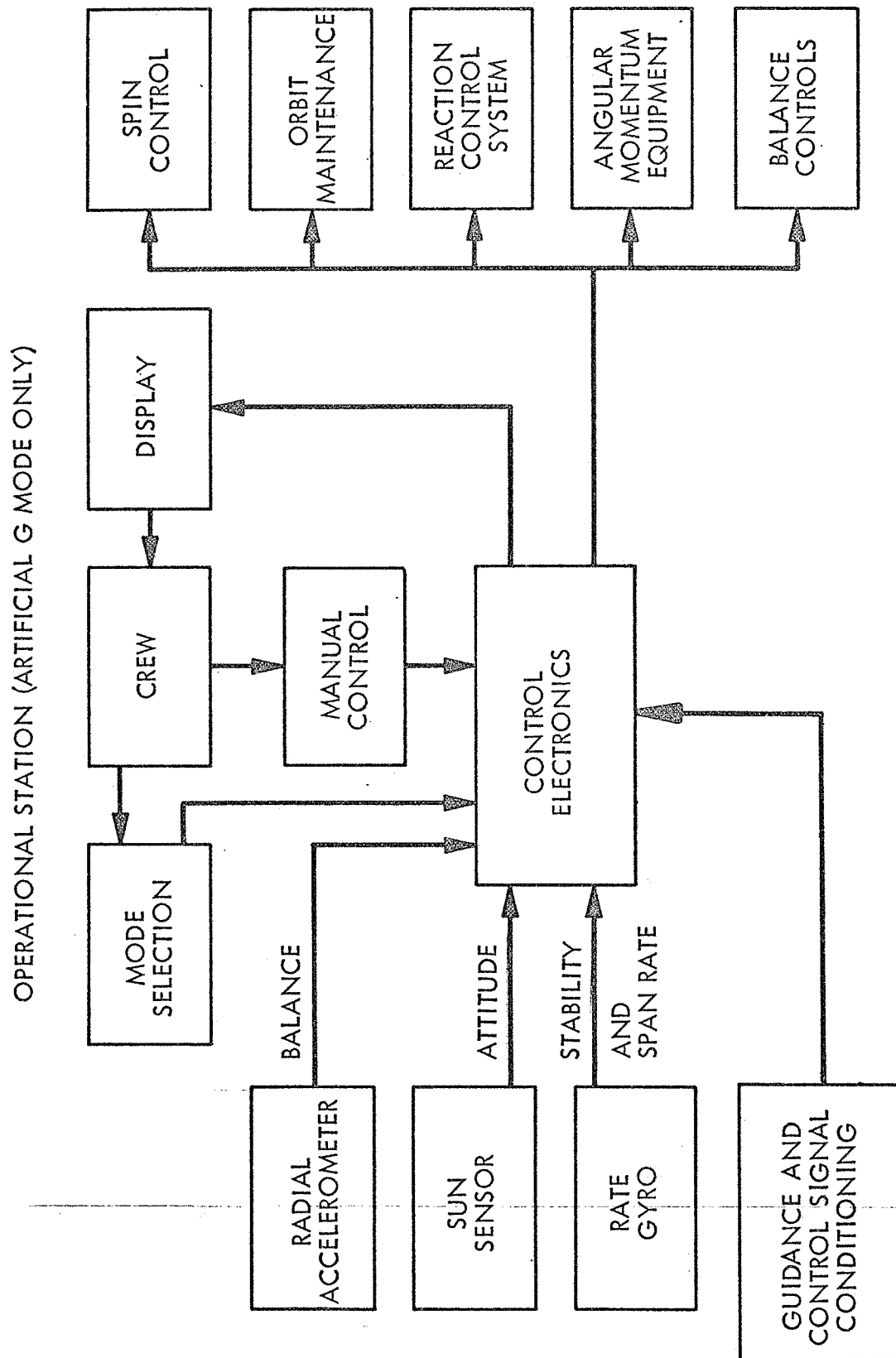


FIG. 4-32 FUNCTION DIAGRAM, ATTITUDE CONTROL AND STABILIZATION SUBSYSTEM

goals for Stabilization and Control component performance. Consideration shall be given to the philosophy of stabilizing the experimental equipment instead of the station if this procedure would result in a weight saving.

#### 4.2.6.3 Design Requirements

The Stabilization and Control Subsystem shall meet the general requirements stated in Section 4.2.

The subsystems shall be functionally arranged as shown in Figs. 4-31 and -32.

Subsystems utilizing Apollo equipment shall attain reliability through designed redundancy, on-board maintenance, and the use of spares.

#### 4.2.7 Propulsion

Requirements for the propulsion subsystems of the Interim Station and Operational Station are presented in this section. The One and Two Compartment Laboratories utilize unmodified Apollo propulsion subsystems; therefore, the subsystems for these laboratories are not included in this preliminary specification.

Propulsion subsystems consist of engines for orbit injection, altitude maintenance, and attitude correction; propellant tanks and plumbing; and pressurization components for the propellant tanks.

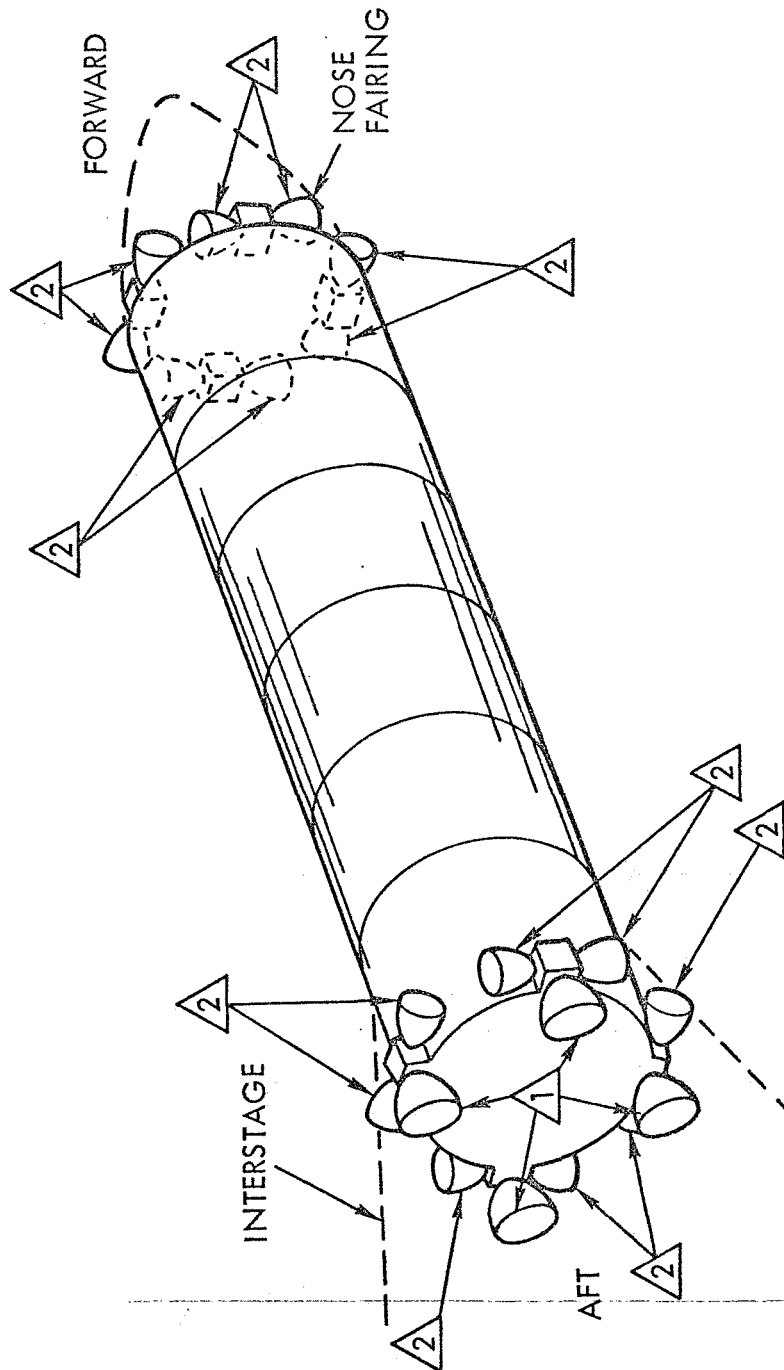
##### 4.2.7.1 Description

Orbit Injection Engines - Interim Station. Four 200-lb thrust engines, mounted as shown in Figure 4-33, accomplish orbit injection, maintain station altitude, and de-orbit the station at the end of the mission. Geometry of the engines is shown in Figure 4-34 and characteristics are listed in Table 4-27.

Attitude Control Engines - Interim Station. Attitude control is provided by 16 80-lb thrust engines mounted as shown in Fig. 4-33. Geometry of the engines is shown in Fig. 4-35 and characteristics are listed in Table 4-28.

Propellant Feed-Interim Station. Propellants are fed to all propulsion engines from a centrally located group of four tanks. The tanks are pressurized by nitrogen and are interconnected as shown in Fig. 4-36. Details of the various tanks and pressurants are given in Table 4-29.

Orbit Injection Engine - Operational Station. The orbit injection portion of the propulsion subsystem utilizes as a prime candidate, the LEM Descent engine modified slightly to suit the needs of the space station. The modifications are 1) elimination of the thrust modulating injector assembly and replacement with a fixed thrust injector, and 2) replacement of the ablative-radiative nozzle assembly with a fully ablative nozzle assembly. Main characteristics of the pressure-fed

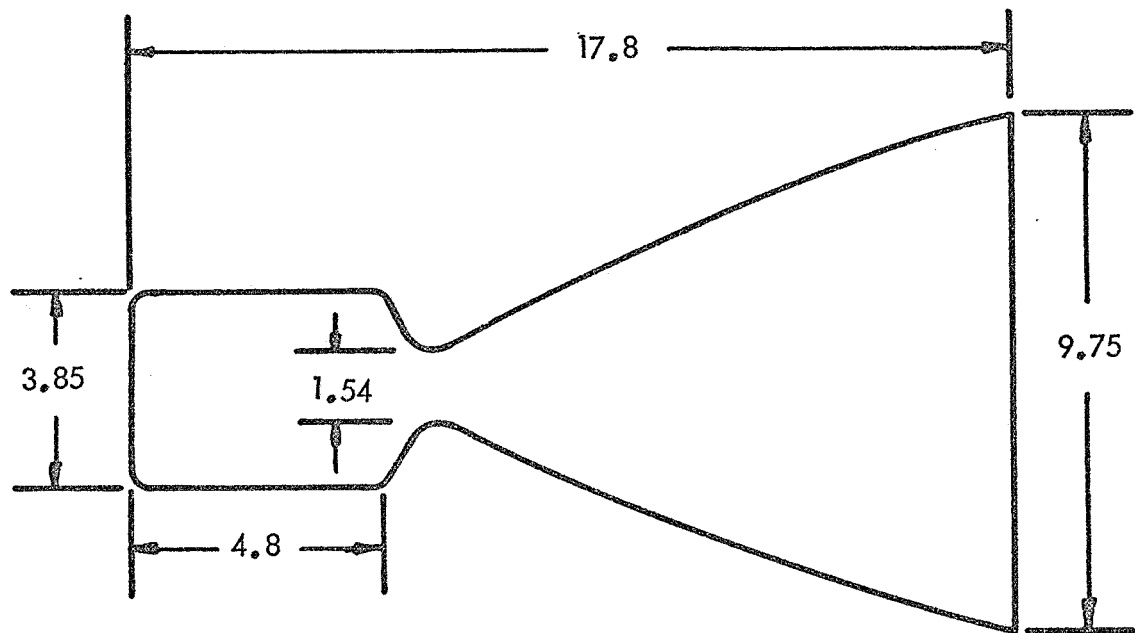


NOTE:

- 1 ORBIT INJECTION ENGINES
- 2 ATTITUDE CONTROL ENGINES

FIG. 4-33 PROPULSION ENGINE LOCATIONS FOR THE INTERIM SPACE STATION



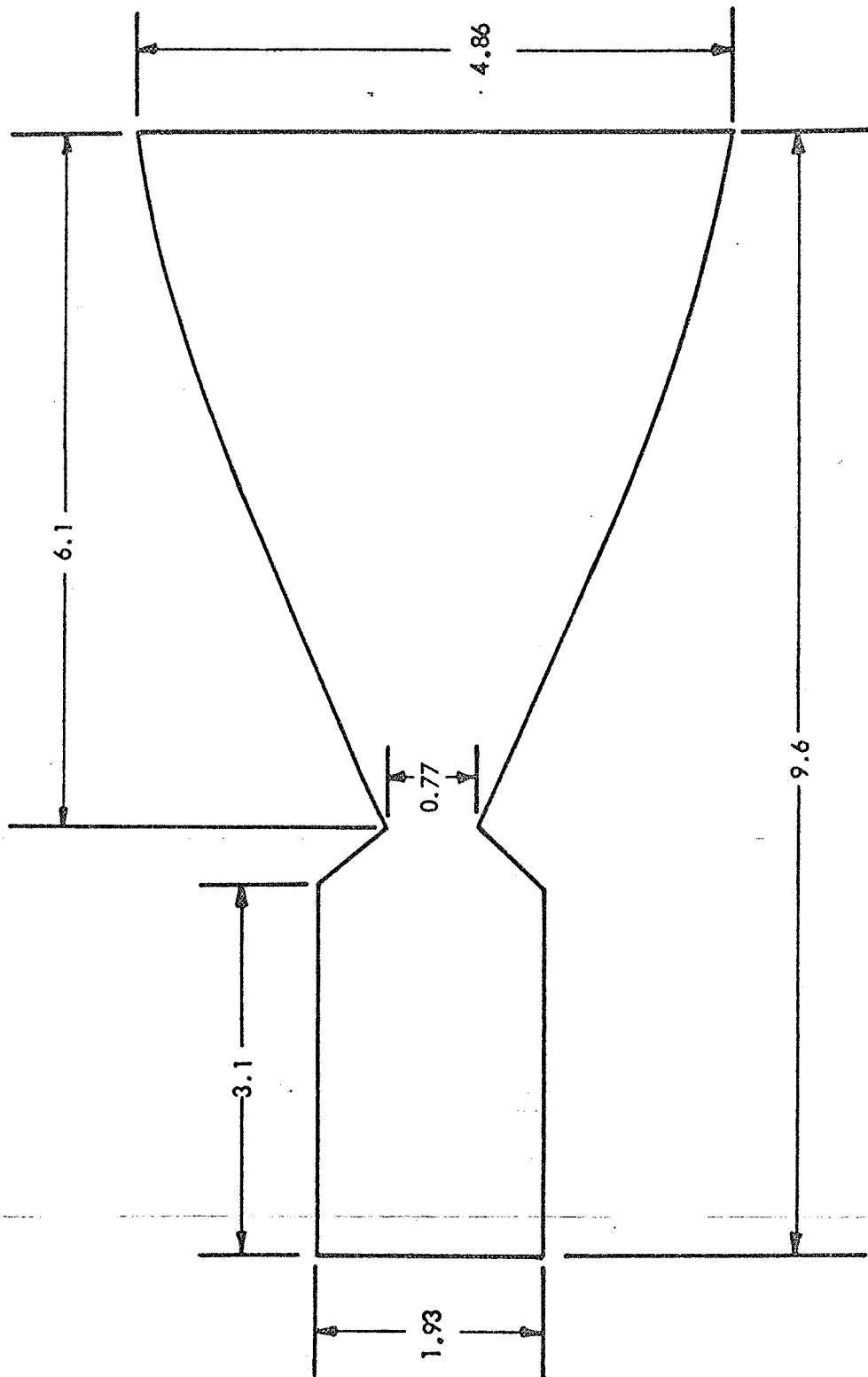


THRUST: 200 LB

EXPANSION RATIO: 40

ALL DIMENSIONS IN INCHES

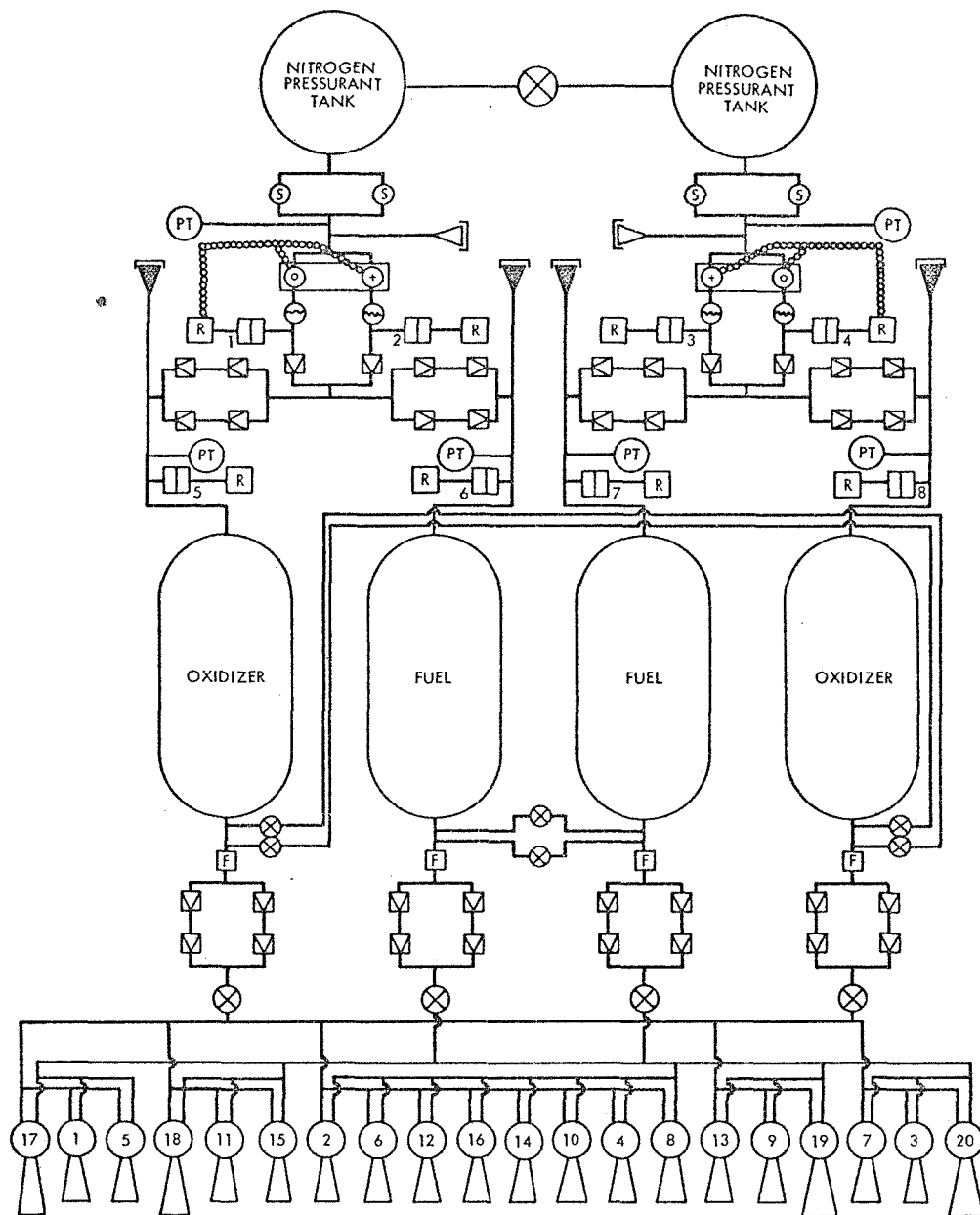
FIGURE 4-34 THRUST CHAMBER GEOMETRY - INTERIM STATION ORBIT  
INJECTION AND OPERATIONAL STATION POST-  
DEPLOYMENT ATTITUDE CONTROL



NOT TO SCALE  
EXPANSION RATIO: 40  
THRUST: 80 LB

ALL DIMENSIONS IN INCHES

FIGURE 4-35 THRUST CHAMBER GEOMETRY - INTERIM STATION ATTITUDE CONTROL AND OPERATIONAL STATION, PRE-DEPLOYMENT ATTITUDE CONTROL



NOTE: ENGINE VALVE CLUSTERS ELIMINATED FOR CLARITY

- |                                      |                          |  |
|--------------------------------------|--------------------------|--|
| [F] FILTER                           | [BD] BURST DISK          | ----- SIGNAL LINE  |
| ⊕ SQUIB VALVE NORMALLY OPEN (n.o.)   | [R] RELIEF VALVE         | [⊕ ⊕] CLUSTERED VALVES WITH COMMON REDUNDANT ACTUATOR  |
| + SQUIB VALVE NORMALLY CLOSED (n.c.) | ▷ FILL CONNECTION        | Ⓢ SOLENOID VALVE   |
| ~ PRESSURE REGULATOR                 | ✓ CHECK VALVES (ONE WAY) | ▶ OPTIONAL - FOR GROUND CHECK OF PRESSURE OR VAPOR GAS LEAKS<br>ALTERNATIVE: REMOVAL OF BURST DISK<br>NUMBERS 5, 6, 7, 8 |
| (P1) PRESSURE TRANSDUCER             | [ ] CAP                  |  |
| ⊗ ON - OFF VALVE                     |                          |  |

THRUSTERS 1 THROUGH 16 ARE 80-LB; 17 THROUGH 20 ARE 200-LB

FIG. 4-36 PROPELLANT FEED SYSTEM - INTERIM STATION

Table 4-27

ENGINE CHARACTERISTICS FOR  
INTERIM STATION ORBIT INJECTION AND OPERATIONAL  
STATION POST-DEPLOYMENT ATTITUDE CONTROL

Total Impulse (Orbit Injection)	460,000 lb-sec
Unmanned Orbit Keeping (1st 20 days)	95,400 lb-sec
Orbit Keeping (6-month period)	215,000 lb-sec
Thrust Level per Engine	200 lb
Number of Engines	4
Orbit Injection Burn Time	317 sec (Perigee) 286 Sec (Apogee)
Propellant Tank Pressure	150 psia
Chamber Pressure	60 psia
Expansion Ratio	40:1
Propellants	$N_2O_4 / (50-50)UDMH-N_2H_4$
Oxidizer/Fuel Ratio	1.6
Specific Impulse (Vacuum-steady state)	312 sec
Engine Cooling Method	Radiative
Operational Modes	
Minimum pulse width*	100 milliseconds
Maximum pulse width*	600 milliseconds
Continuous	
Life Expectancy	3600 sec

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\* Post-Deployment Attitude Control Only

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Table 4-28

ENGINE CHARACTERISTICS, INTERIM STATION ATTITUDE CONTROL AND  
OPERATIONAL STATION PRE-DEPLOYMENT ATTITUDE CONTROL

Total Attitude Control Impulse (Normal operation - 180 days)	324,000 lb-sec
Attitude Control (unmanned - 20 days)	75,400 lb-sec
Attitude Control (Normal operation - 160 days)	248,600 lb-sec
Thrust Level per Engine	80 lb
Number of Engines	16 (8 forward, 8 aft)
Chamber Pressure	60 psia
Propellant Tank Pressure	150 psia
Expansion Ratio	40:1
Propellants	$N_2O_4$ /50 percent UDMH - 50 percent $N_2H_4$
Oxidizer/Fuel Ratio	1.6
Specific Impulse	
• Steady State	312 sec
• Pulsed	285 sec
Engine Cooling Method	Radiative
Minimum Pulse Width	60 milliseconds
Life Expectancy	6280 sec

Table 4-29  
PROPELLANT FEED SUBSYSTEM CHARACTERISTICS  
FOR THE INTERIM SPACE STATION

Propellant Tank Pressure	150 psia
Oxidizer	$N_2O_4$
Fuel	50 percent UDMH - 50 percent $N_2H_4$
Number of Propellant Tanks	4 (2 oxidizer, 2 fuel)
Propellant Tank Geometry	Cylindrical
Propellant Tank Diameter (I.D.)	22.5 in.
Propellant Tank Length	36 in.
Oxidizer Tank Volume, Total	14.4 cu ft
Fuel Tank Volume, Total	14.4 cu ft
Propellant Tank Material	Titanium
Expulsion Device	Metal bellows
Expulsion Device Material	Titanium or Stainless Steel
Pressurant Tank Pressure-Initial	3000 psia
Pressurant Tank Pressure-Final	150 psia
Pressurant	Nitrogen
Pressurant Tank Geometry	Spherical
Pressurant Tank Diameter	15.3 in.
Number of Pressurant Tanks	2
Pressurant Tank Material	Titanium
Pressurant Tank Volume	1.1 cu ft per tank

engine are given in Table 4-30. A schematic of the components is given in Fig. 4-37. The engine, which is gimballed to provide thrust vector control, is mounted as shown in Fig. 4-38 and -39.

Pre-Deployment Attitude Control Engines - Operational Station. Pre-deployment attitude control is provided by eight radiation-cooled engines mounted on the hub as shown in Fig. 4-39. The characteristics of the engines, which are the same engines that are used on the attitude control system of the Interim Station, are given in Table 4-28. Geometry of the engines is shown in Fig. 4-35.

Post-Deployment Attitude Control Engines - Operational Station. Eighteen engines, having the characteristics given in Table 4-27, provide post-deployment attitude control. The engines are the same engines used for orbit injection on the Interim Station. They are mounted in clusters of six, one cluster at the outermost end of one access tube of each module as shown in Fig. 4-40. The clusters are retractable within the access tubes for servicing. Figure 4-41 shows the plumbing arrangements within the modules.

Propellant Feed System - Operational Station. The fuel for all the engines on the Operational Station is  $N_2H_4$ -UDMH (50-50); the oxidizer is  $N_2O_4$ . Three sets of propellant tanks are provided:

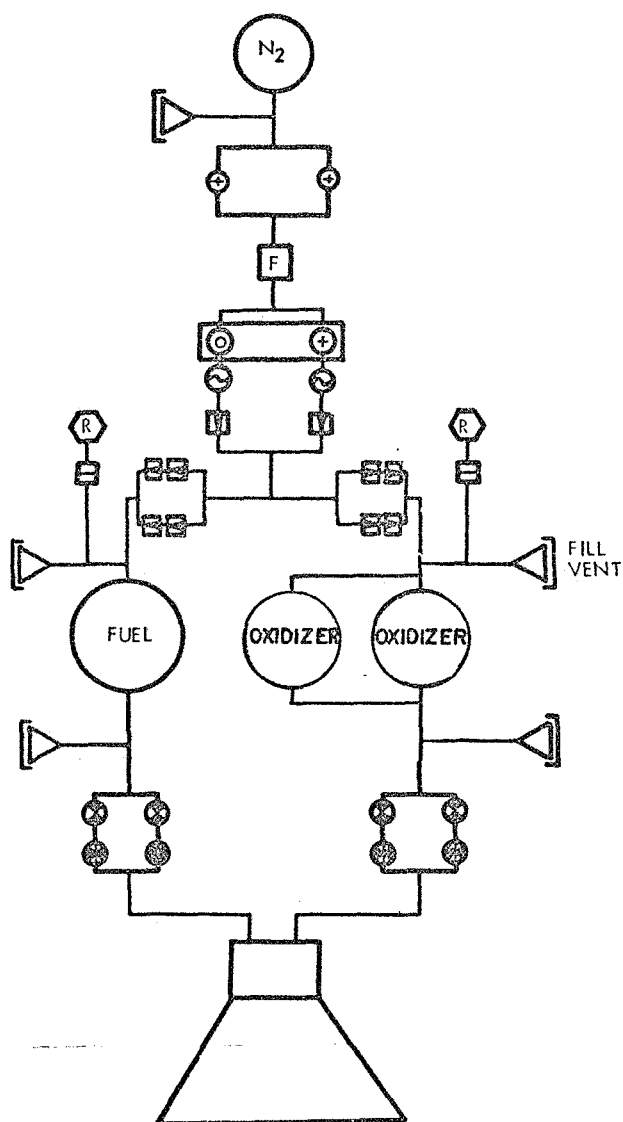
- Tanks for the orbit injection engine are attached to the jettisonable engine mount as shown in Fig. 4-38. The tanks are pressurized by nitrogen.
- Tanks for the pre-deployment attitude control engines are located in the hub as shown in Fig. 4-42. The nitrogen pressurant tank is also shown in this figure. The hub-mounted propellant tanks constitute a central resupply point for the post-deployment attitude control engine propellant tanks.
- Tanks for the post-deployment attitude control engines are mounted outside the module access tubes near the outer ends as indicated in Fig. 4-40. Dual nitrogen pressurant tanks are provided as shown in Fig. 4-41.

Table 4-30

ORBIT INJECTION ENGINE CHARACTERISTICS-OPERATIONAL STATION

Total Impulse	2,090,000 lb-sec
Thrust	10,500 lb
Duration	198 sec
Chamber Pressure	110 psia
Expansion Ratio	47.5
Cooling Method	Fully ablative
Thrust Vector Control	Gimbaling ( $\pm 6$ deg)
Propellants	$N_2O_4/(50-50)$ UDMH- $N_2H_4$
Oxidizer/Fuel Ratio	1.6
$I_{sp}$	307.5 sec
Propellant Weight:	
Oxidizer	4400 lb
Fuel	2750 lb
Tank Geometry	Spherical
Tank Material	Titanium
Tank Pressure	225 psia
Oxidizer	24.5 cu ft (2 tanks)
Fuel	49.0 cu ft
Nitrogen Weight	89.8 lb
Nitrogen Bottle Diameter	2.14 ft
Nitrogen Bottle Pressure	3600 psia
Positive Expulsion Technique	Metal Bellows or Bladders

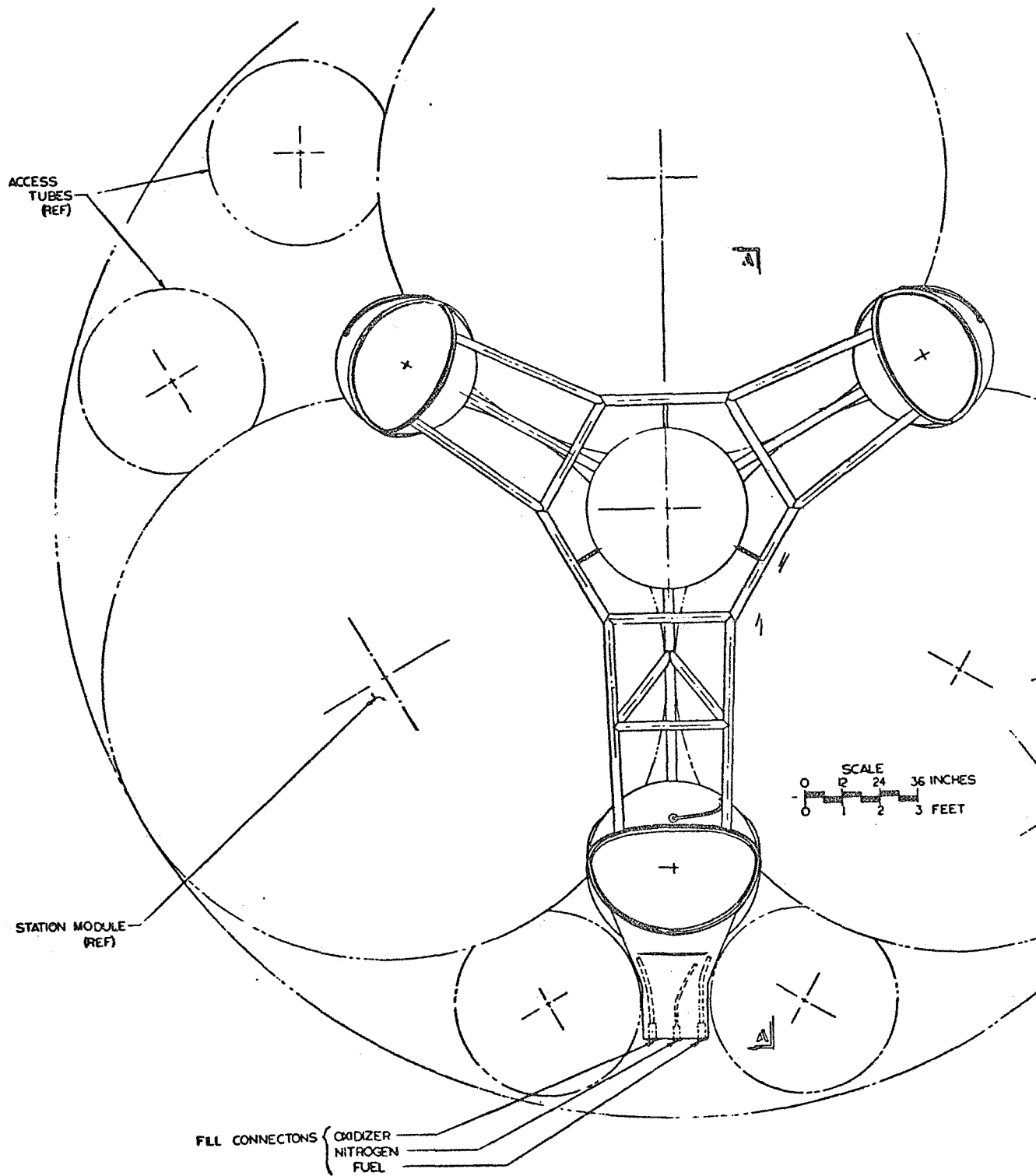




NOMENCLATURE	
	SQUIB VALVE NORMALLY OPEN
	SQUIB VALVE NORMALLY CLOSED
	PRESSURE REGULATOR
	ON/OFF VALVE
	BURST DISC
	FILTER
	RELIEF VALVE
	CHECK VALVE
	FILL OR VENT CONNECTION
	CAP
	CLUSTERED VALVE WITH REDUNDANT ACTUATOR
N <sub>2</sub>	NITROGEN GAS
	ENGINE PROPELLANT VALVES

FIG. 4-37 ORBIT INJECTION SUBSYSTEM SCHEMATIC DIAGRAM,  
OPERATIONAL STATION





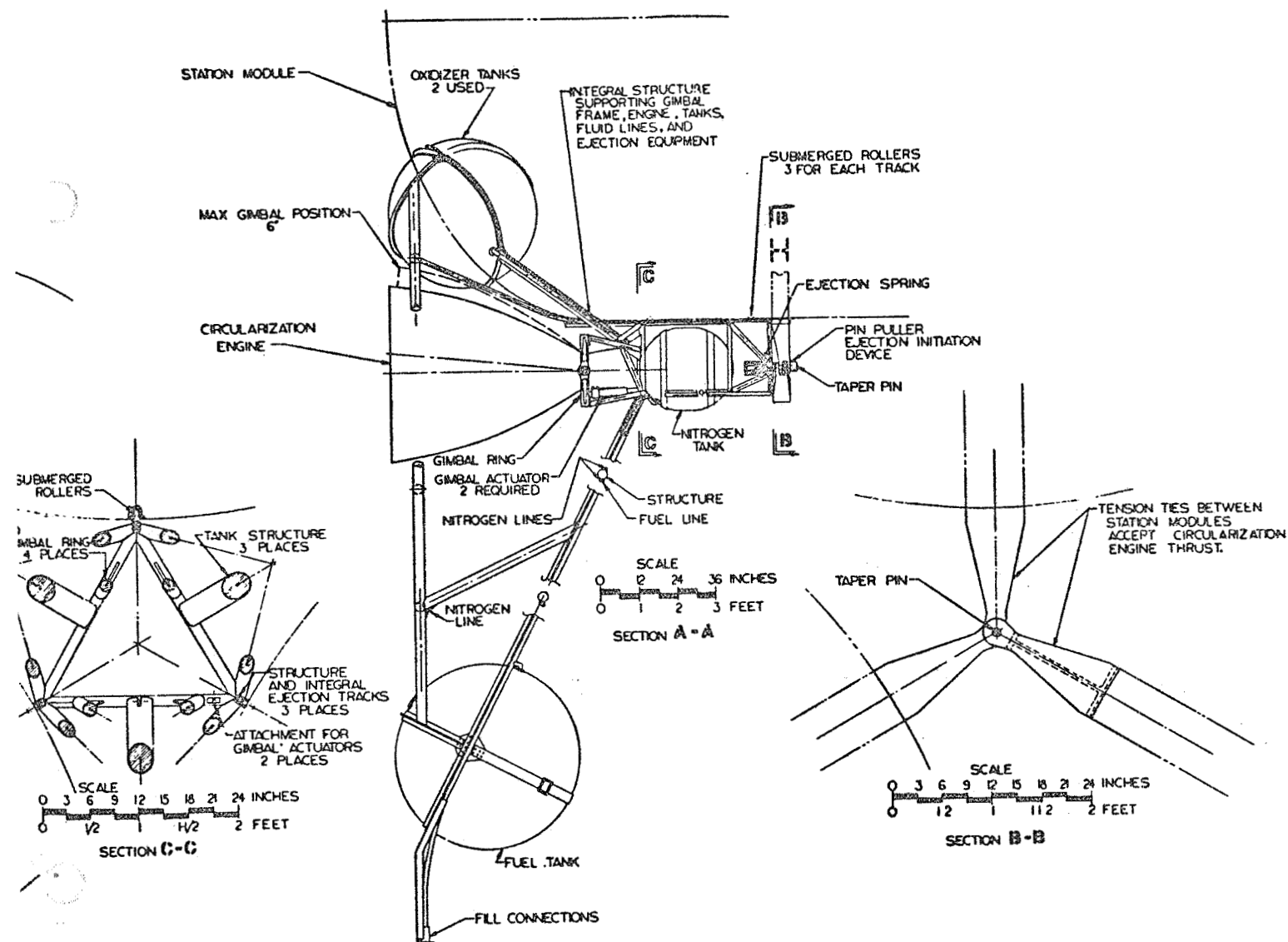


FIG. 4-38 ORBIT INJECTION ENGINE INSTALLATION FOR THE OPERATIONAL STATION



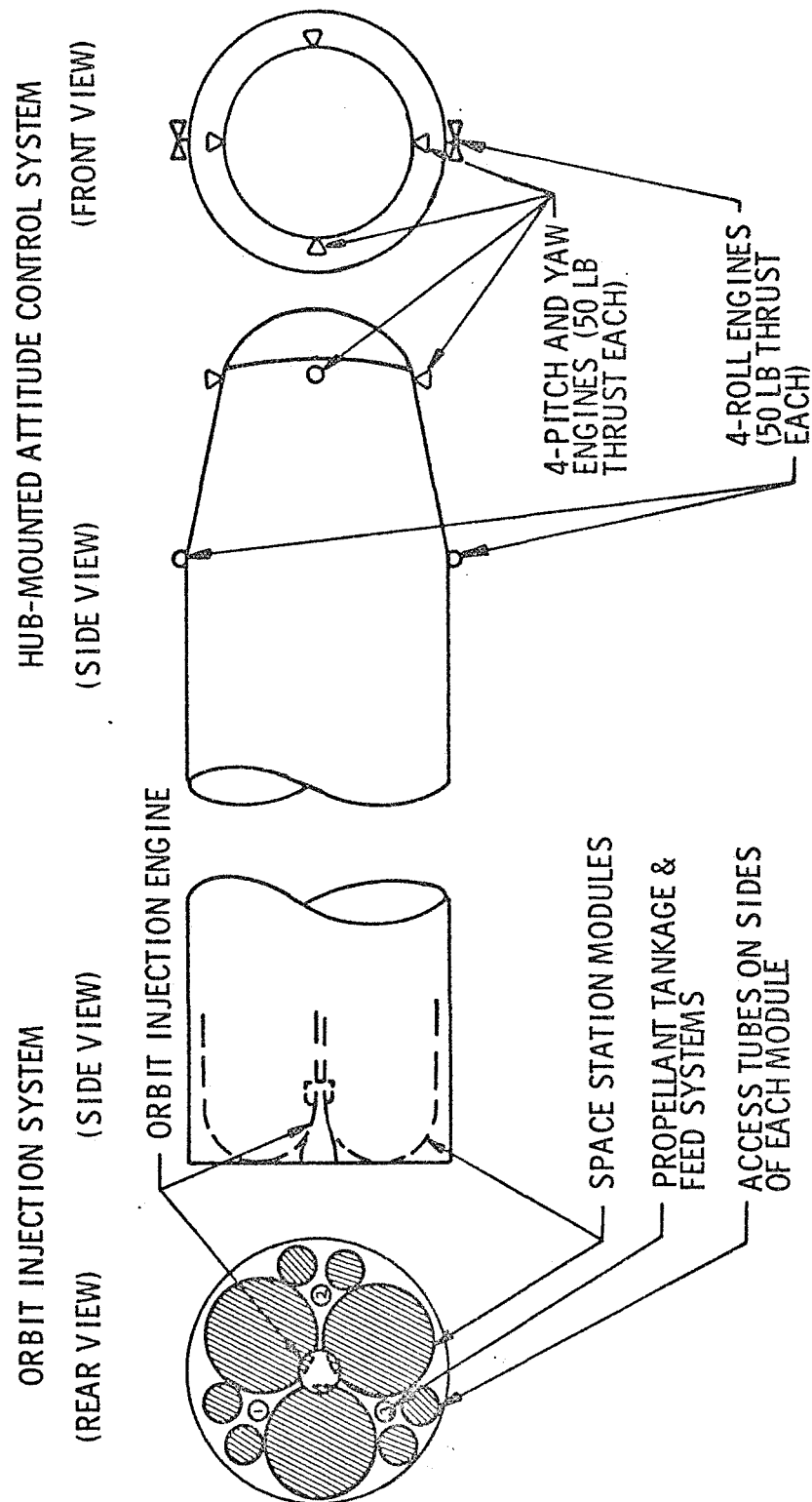


FIG. 4-39 LOCATION OF ORBIT INJECTION AND HUB MOUNTED ATTITUDE CONTROL ENGINES ON THE OPERATIONAL SPACE STATION

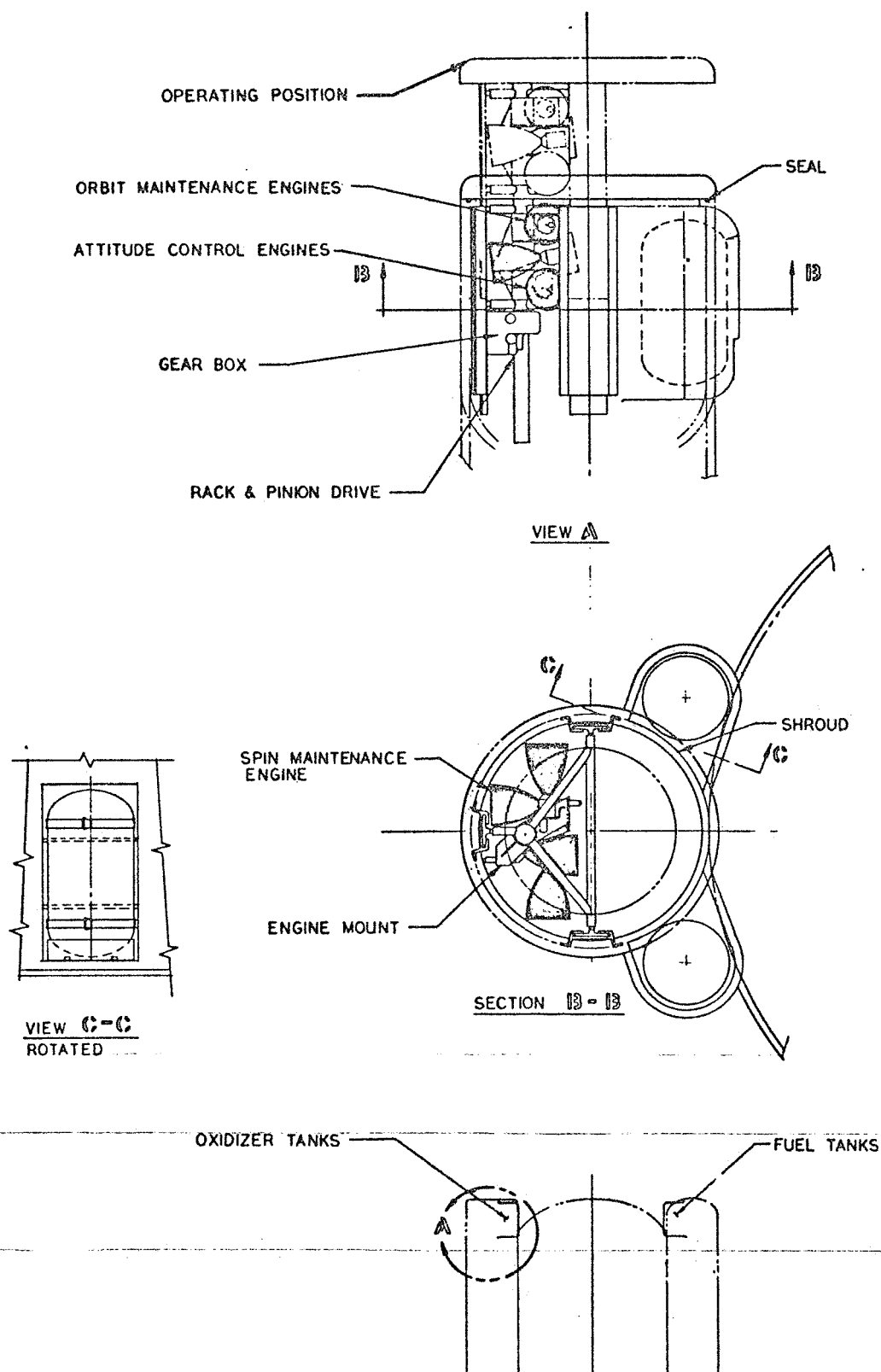


FIG. 4-40 ATTITUDE CONTROL ENGINES INSTALLATION FOR THE OPERATIONAL STATION

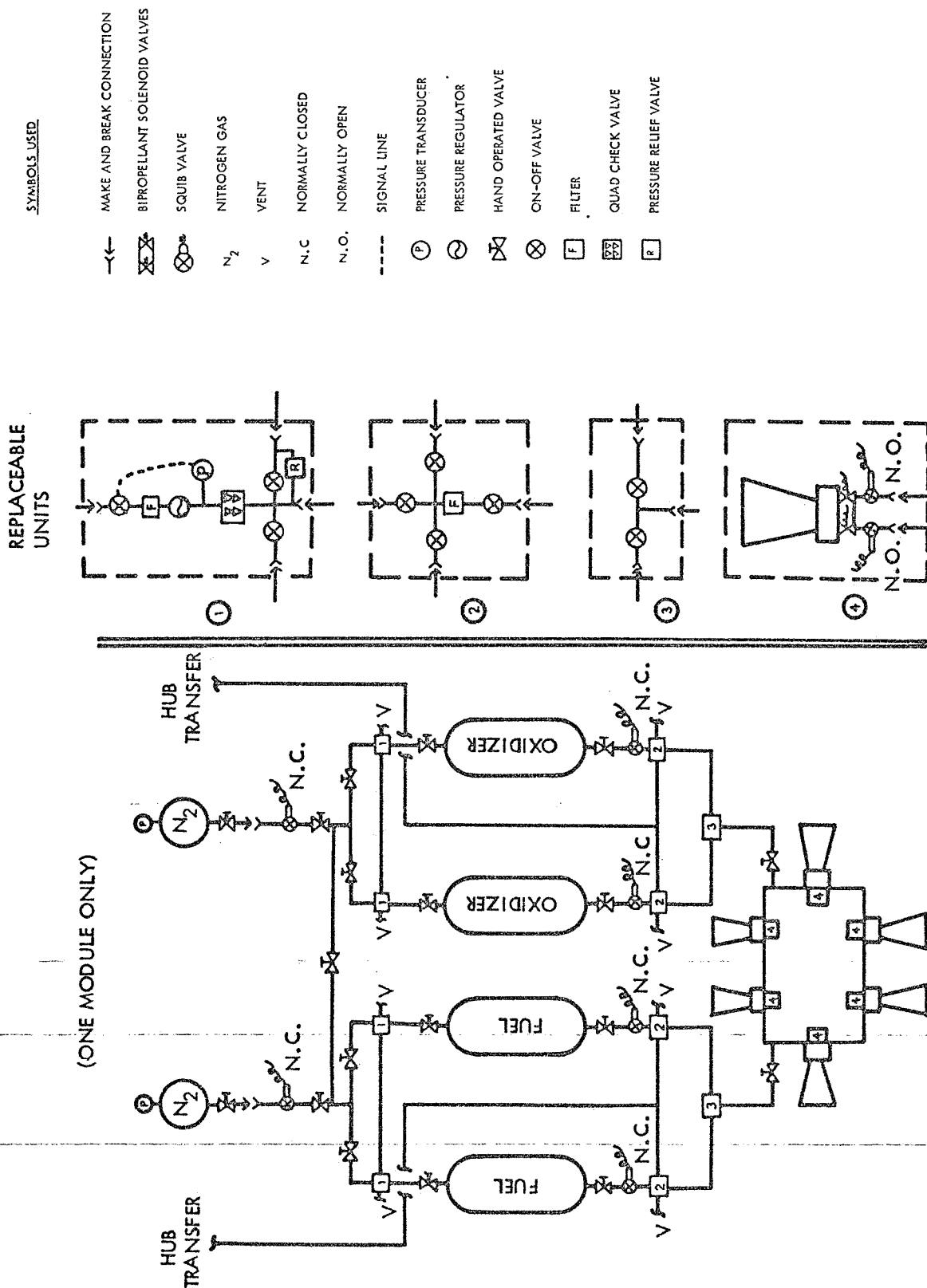


FIG. 4-41 POST-DEPLOYMENT ATTITUDE CONTROL SYSTEM SCHEMATIC DIAGRAM FOR THE OPERATIONAL SPACE STATION



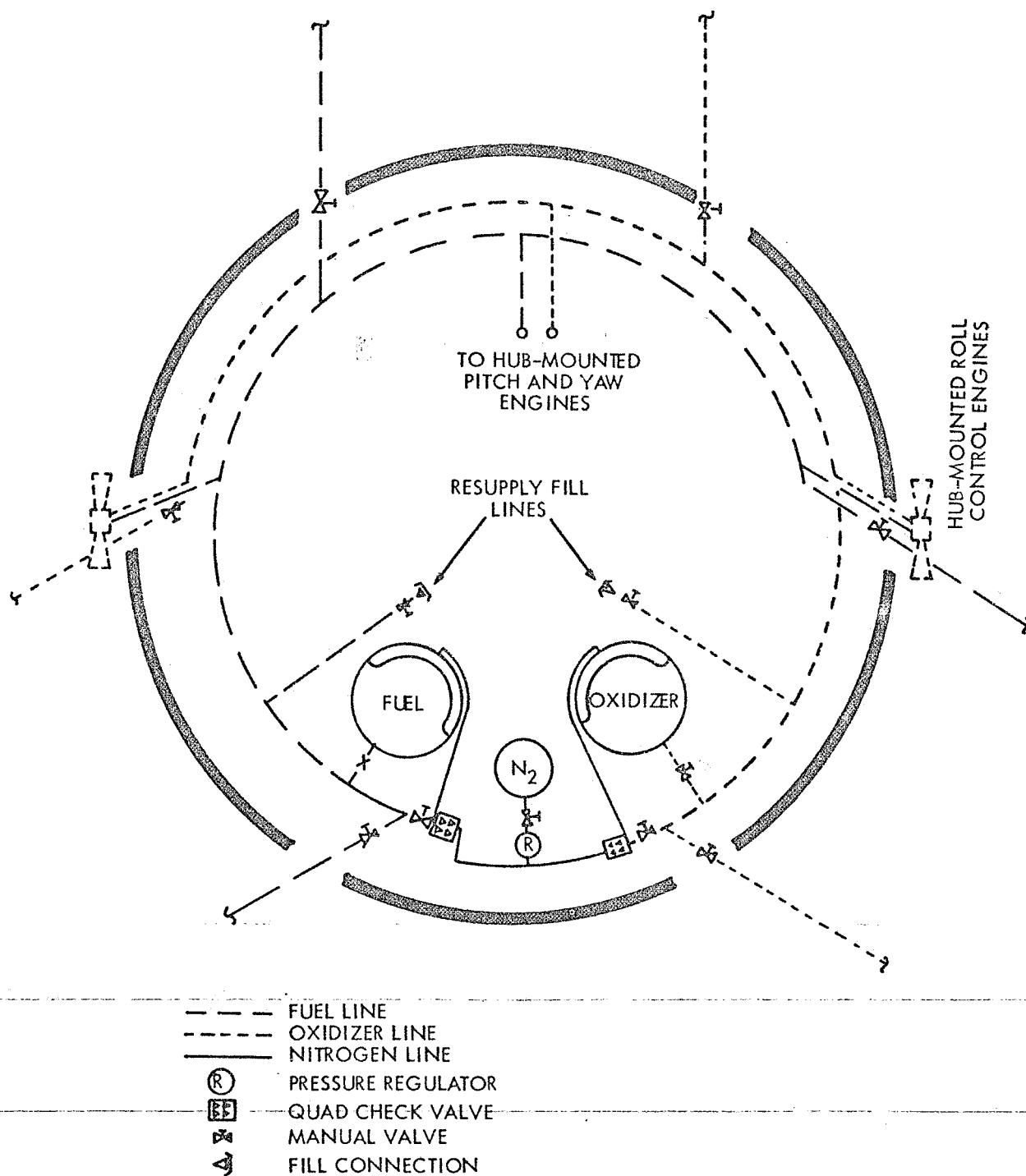


FIG. 4-42 PROPELLANT TRANSFER AND STORAGE (HUB AREA) FOR THE OPERATIONAL STATION

4.2.7.2 Performance Requirements

The propulsion engines shall meet the performance requirements specified in the tables referenced below:

<u>Engine</u>	<u>Performance Requirements Specified by Table No.</u>
Orbit Injection - Interim Station	4-27
Attitude Control - Interim Station	4-28
Orbit Injection - Operational Station	4-30
Pre-Deployment Attitude Control - Operational Station	4-28
Post-Deployment Attitude Control - Operational Station	4-27

4.2.4.3 Design Requirements

All propulsion subsystems and their components shall meet the general requirements of Section 4.2.

The orbit injection engines of the Interim Station and the post-deployment attitude control engines of the Operational Station shall be basically similar.

The attitude control engines of the Interim Station and the pre-deployment attitude control engines of the Operational Station shall be similar.

The orbit injection unit of the Operational Station shall consider the LEM descent engine as a prime candidate. The engine shall be gimbaled to permit + 6 deg of angular motion about two axes.

Engine locations shall be as specified below:

<u>Engines</u>	<u>Location Specified by Figure No.</u>
Orbit Injection - Interim Station	4-33
Attitude Control - Interim Station	4-33
Orbit Injection - Operational Station	4-39

<u>Engines</u>	<u>Location Specified by Figure No.</u>
Pre-Deployment Attitude Control - Operational Station	4-39
Post-Deployment Attitude Control - Operational Station	4-40

All propulsion engines shall be designed to utilize  $N_2H_4$ -UDMH (50-50) as fuel and  $N_2O_4$  as oxidizer.

The orbit injection engine system of the Operational Station shall be jettisonable as a unit and shall be arranged as indicated in Fig. 4-38.

The propellant feed and pressurization subsystems for the various propulsion engines shall be functionally arranged as indicated by the figures listed below.

<u>Engines</u>	<u>Propellant Feed &amp; Pressuriza- tion Specified by Figure No.</u>
Orbit Injection - Interim Station	4-36
Attitude Control - Interim Station	4-36
Orbit Injection - Operational Station	4-37
Pre-Deployment Attitude Control - Operational Station	4-42
Post-Deployment Attitude Control - Operational Station	4-41

Propellant resupply on the Operational Station shall be to the hub-mounted tanks. The post-deployment attitude control engines shall receive their propellants from the hub-mounted tanks through the plumbing indicated on Figs. 4-41 and -42.

Propellant line plumbing connections on all propulsion subsystems shall either be welded or shall utilize fittings which will restrict leakage to a minimum specified rate.

Propellant tanks shall be equipped with positive expulsion devices to assure flow at zero-g. The selection of materials for expulsion devices shall be governed by the principles discussed in the appropriate paragraphs of Section 3.5

Control on the Operational Station shall be arranged to allow the pre-deployment attitude control engines to perform the functions of post-deployment attitude control thus providing a redundant system.

The propulsion subsystem target weights shall be as listed in Tables 4-31 and -32.

Table 4-31  
INTERIM MODULAR SPACE STATION INTEGRATED ORBIT INJECTION &  
ATTITUDE CONTROL PROPULSION SUBSYSTEM WEIGHT

<u>COMPONENT</u>	<u>Weight (lb)</u>	
Thruster System		580
Thrusters	150	
200 Pound Thrust, 4 Required	42	
80 Pound Thrust, 16 Required	108	
Propellant Tanks & Structure	250	
Pressurant Tanks (2)	75	
Nitrogen Pressurant	40	
Plumbing Valves & Supports	65	
Propellant		4100
Oxidizer	2520	
Fuel	1580	
Total Subsystem Weight-Wet		4680

Table 4-32

OPERATIONAL MODULAR MULTIPURPOSE SPACE STATION PROPULSION  
SUBSYSTEM WEIGHT

<u>COMPONENT</u>	<u>Weight (lb)</u>	
ORBIT INJECTION SUBSYSTEM WEIGHT		
Engine System		1629
Engine	350	
Propellant Tanks & Structure	652	
Pressurant Tank	178	
Nitrogen Pressurant	90	
Retro Package & Structure	359	
Propellant		7150
Oxidizer	4400	
Fuel	2750	
Total System Weight-Wet		8779

## HUB MOUNTED ATTITUDE CONTROL PROPULSION SUBSYSTEM WEIGHT

Thruster System		280
Thrust Chambers (8) Required	54	
Propellant Tanks & Structure	104	
Pressurant Tank	38	
Nitrogen Pressurant	21	
Plumbing & Valves	63	
Propellant		1526
Oxidizer	939	
Fuel	587	
Total System Weight-Wet		1806

Table 4-32 (cont)

OPERATIONAL MODULAR MULTIPURPOSE SPACE STATION PROPULSION  
SUBSYSTEM WEIGHT

<u>COMPONENT</u>	<u>Weight (lb)</u>	
POST-DEPLOYMENT ATTITUDE CONTROL PROPULSION SUBSYSTEM WEIGHT		
Thruster System		1878
Thrust Chambers (18)	198	
Propellant Tanks & Structure	1002	
Pressurant Tanks (6)	120	
Nitrogen Pressurant	112	
Plumbing & Valves	446	
Propellant		8474
Oxidizer	5215	
Fuel	3259	
Total System Weight-Wet		<u>10,352</u>